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(54) Title: APPARATUS AND METHOD FOR PERFORMING IMAGING AND DOWNHOLE OPERATIONS AT WORK SITE IN WELLBORES			
(57) Abstract			
<p>The present invention provides a downhole service tool for imaging a location constituting a work site of interest downhole at which a tool operation is to be performed in a preexisting wellbore and for performing a tool operation at the work site during a single trip of the tool. The downhole service tool includes an imaging device which sensors properties associated with the work site and generates data representative of the work site. The imaging data is transmitted to the surface via a two-way telemetry system. An end work device in the downhole service tool performs the desired tool operation at the desired work site. The service tool images the work site, communicates imaging data to the surface and performs the desired operation during a single trip into the wellbore.</p>			

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PATENT APPLICATION

**TITLE: APPARATUS AND METHOD FOR PERFORMING IMAGING AND
DOWNHOLE OPERATIONS AT WORK SITE IN WELLBORES**

Field of the Invention

5 This invention relates generally to downhole tools for use in wellbores and more particularly to tools which can image a work site or an object in a wellbore, communicate with the surface and perform a desired end work or service at the work site, during a single trip in the wellbore. The present invention also provides novel imaging devices and end work devices and various
10 downhole tool configurations for imaging worksites and performing the desired end works.

Background of the Invention

15 To produce hydrocarbons (oil and gas) from the earth's formations, wellbores (also referred to in industry as boreholes) are formed to desired depths. The shallow portion of the wellbore is typically large in diameter, which is lined with a metal casing to prevent caving of the wellbore. The wellbore is then drilled to a desired depth to recover hydrocarbons from the subsurface
20 formations. After the wellbore has been drilled, a metal pipe, generally referred to in the art as the casing or pipe, is set in the wellbore by injecting cement

5 through the annulus between the casing and the wellbore. Branch or lateral wellbores are frequently drilled from a main wellbore to form deviated or horizontal wellbores for improving production of hydrocarbons from the subsurface formations.

10 A large proportion of the current drilling activity involves directional drilling, i.e., drilling deviated and horizontal wellbores, to improve the hydrocarbon production and/or to withdraw additional hydrocarbons from the earth's formations. The wellbores are then completed and put into production. The drilling and completion processes involve a number of different operations.

15 Such operations may include cutting and milling operations (including cutting relatively precise windows in the wellbore casings), sealing junctures between intersecting wellbores, welding, re-entering lateral wellbores, perforating, setting devices such as plugs, sliding sleeves, packers and sensors, remedial operations, sealing, stimulating, cleaning, testing and inspection including

20 determining the quality and integrity of a juncture, testing production from a perforated zone or a portion thereof, collecting and analyzing fluid samples, and analyzing cores.

Oilfield wellbores usually continue to produce hydrocarbons for many

25 years. Various types of operations are performed during the life of producing wellbores. Such operations include removing, installing and replacing different

5 types of devices, including fluid flow control devices, sensors, packers or seals, remedial work including sealing off zones, cementing, reaming, repairing junctures, milling and cutting, freeing stuck sleeves, diverting fluid flows, controlling production from perforated zones, setting sleeves, and testing wellbore production zones or portions thereof.

10

Typically, to perform downhole operations at a work site in a preexisting wellbore, whether during the drilling, completion, production, or servicing and maintaining the wellbore, a desired tool is conveyed downhole, positioned into the wellbore at the work site and the desired operation is performed. Most of
15 the prior art tools are substantially mechanical tools or electro-mechanical tools. Such tools lack downhole maneuverability, in that the various elements of the tools do not have sufficient degrees of freedom of movement, lack local or downhole intelligence, do not obtain sufficient data with respect to the work site or of the operation being performed, do not provide an image of the work
20 site during the trip made for performing the end work, and do not provide confirmation of the quality and integrity of the work performed. Such prior art tools usually require multiple trips downhole to image a work site, perform an operation and then to confirm whether the operation has been properly performed. Multiple downhole trips can be very expensive, due to the rig or
25 production down time.

5 The present invention addresses some of the above-noted problems and provides downhole service tools (also referred to as the downhole tool or service tool) which can be positioned and oriented adjacent a desired work site, images of the work site to the surface, perform the desired work at the work site and confirm or inspects the quality of the work during a single trip into a preexisting wellbore. The present invention provides imaging devices, end work devices and various downhole tool configurations to image work sites and to perform desired operations in preexisting wellbores. The imaging devices include an optical viewing device, an inflatable imaging device, ultrasonic devices and a tactile device. The end work devices include cutting devices, reentry devices, 10 sealing devices, welding devices, testing and servicing devices.

SUMMARY OF THE INVENTION

20 The present invention provides a downhole tool for imaging a location constituting a work site of interest in a preexisting wellbore and for performing a tool operation at the work site during a single trip in the wellbore. The downhole tool includes an imaging device for imaging the work site and an end work device for performing a desired operation or an end work at the work site. The imaging device may determine the image downhole and transmit the image 25 to the surface or transmit the image data for processing at the surface. The downhole tool may be conveyed into the wellbore by any suitable method,

5 including a wireline, a tubing, and a robotics device that moves the downhole tool inside the wellbore.

Any suitable imaging device may be utilized for the purpose of this invention, including a camera for optical viewing, microwave device, contact
10 device (tactile device) such as a probe or a rotary device, an acoustic device, ultrasonic device, infra-red device and radio frequency ("RF") device.

The end work devices may include a fishing tool to engage a fish downhole, whipstock, diverter, re-entry tool, packer, seal, plug, perforating tool,
15 fluid stimulation tool, fluid fracturing tool, milling tool, cutting tool, patch tool, drilling tool, cladding tool, welding tool, deforming tool, sealing tool, cleaning tool, tool for installing a device, tool for removing a device; setting device, testing device, an inspection device, acidizing tool, an anchor, and a tool that engages with a downhole object.

20

In the downhole tools of the present invention, one or more devices are provided to position and orient the imaging device and the end work device as desired. Each downhole tool preferably includes a computer or processor and associated memory for storing therein models and programs for controlling the
25 operations of the imaging device and the end work device. A surface computer receives the data from the downhole tool and displays the image of the work

5 site for use by an operator. A two-way telemetry system provides communication between the surface computer and the downhole tool.

The present invention also provides ultrasonic imaging devices, including a device which can image radially and downhole (in front) of the downhole tool.

10 In one mode, the ultrasonic imaging device transmits signals by sweeping a preselected frequency range to obtain an effective operating frequency. The device then continues to operate the transmitter at such effective frequency to generate data representative of the attributes of the work site.

15 The present invention also provides an imaging device for obtaining still and/or video pictures of a work site in the wellbore. This viewing device includes a camera or another suitable device for taking the pictures and a mechanism to displace the non-transparent fluid in the wellbore with a transparent fluid. This invention further provides an inflatable device for
20 providing the image of an object in the wellbore when such device is inflated and urged against the object.

The downhole tool may further include sensors for providing information about the condition of the downhole tool in the wellbore. Such sensors may
25 include sensors for determining temperature, pressure, fluid flow, pull force, gripping force, tool centerline position, tool configuration, inclination, and

5 acceleration. Formation evaluation sensors and other sensors to log the wellbore may also be included in the downhole tool of the present invention.

The present invention also provides certain end work devices, including a high pressure fluid cutting tool, which includes a source of supplying a fluid at a relatively high pressure and a cutting element for discharging the high pressure fluid. The fluid source may include serially arranged pressure stages, wherein each such stage increases the fluid pressure above its preceding stage. The fluid may be pulsed prior to supplying it to the cutting element. A control unit controls the position and orientation of the cutting element relative to the work site. The control unit may be programmed to cut according to a predetermined pattern provided to the control unit.

In each of the downhole tools of the present invention, the operation of the imaging device and the end work device may be controlled from the surface and/or by the computer or processor in the downhole tool.

Examples of the more important features of the invention have been summarized rather broadly in order that the detailed description thereof that follows may be better understood, and in order that the contributions to the art may be appreciated. There are, of course, additional features of the invention that will be described hereinafter and which will form the subject of the claims

5 appended hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

For a detailed understanding of the present invention, reference should be made to the following detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings, in which like elements have been given like numerals, and wherein:

10

FIGS. 1 and 1A are schematic diagrams of a system utilizing a service tool conveyed into a wellbore for imaging a work site in the wellbore and performing a desired operation at the work site during a single trip according to one embodiment of the present invention.

15

FIG. 2 is a schematic diagram of a pressurized fluid cutting tool as an end work device for use in the system of **FIG. 1**.

20

FIG. 2A shows a manner of positioning the cutting element of the cutting tool shown in **FIG. 2** in a wellbore to cut material located downhole of the cutting tool.

FIG. 2B-C show alternative ways to position the cutting element of the downhole cutting tool shown in **FIG. 2** to cut materials located downhole of the

25

5 cutting tool.

FIG. 3 is an example of a predetermined profile of a section of the casing to be cut that may be stored in a memory associated with the cutting system of FIG 1.

10

FIG. 4 is a schematic diagram of the cutting tool shown in FIG. 1 with a downhole imaging device for obtaining images of areas to be cut before and after the cutting operation.

15

FIG. 5A is a schematic diagram of an embodiment of a downhole (service) tool having an ultrasonic imaging sensor for imaging a work site downhole of the service tool and an end work device for performing a desired operation at the work site during a single trip.

20

FIG. 5B is a schematic diagram of an alternative embodiment of a downhole tool having an ultrasonic imaging sensor for radially imaging a work site and an end work device for performing a desired operation at the work site during a single trip.

25

FIG. 5C is a schematic diagram of yet another embodiment of a downhole service tool having an ultrasonic imaging sensor for radially imaging a work site

5 and an end work device for performing a desired operation at the work site during a single trip.

FIG. 5D shows the downhole service tool of FIG. 5A positioned adjacent a wellbore juncture desired work site in a preexisting wellbore.

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FIG. 6A shows a schematic diagram of an embodiment of an imaging tool for obtaining still and/or video pictures of object downhole.

FIG. 6B shows a schematic diagram of the imaging tool of FIG. 5D positioned adjacent to a juncture between a main wellbore and a branch wellbore.

20

FIG. 6C shows a schematic diagram of an inflatable imaging tool position at a wellbore juncture for determining a contour of the juncture.

FIG. 6D shows a configuration of the placement of sensors in the inflatable member used in the imaging tool of FIG. 5F.

FIG. 7 is a schematic diagram of an embodiment of a downhole tool having an imaging device and a milling tool disposed at a bottom end of the tool for imaging a work site and performing a milling or cutting operation at the work

5 site during a single trip.

FIG. 8A is a schematic diagram of an embodiment of a downhole tool having an imaging device and an end work device for use in lateral wellbore operations.

10

FIGS. 8B-8D are schematic diagrams of downhole tools with an imaging device and re entry device.

FIG. 9 is a schematic diagram of an embodiment of a downhole tool having an imaging device and an inflatable packer wherein the imaging device is adapted to obtain images during setting of the inflatable packer in a wellbore.

FIGS. 10A-10B are schematic diagrams of an embodiment of a downhole service tool having an imaging device and a welding device disposed for imaging a work site and performing a welding operation at the work site.

FIG. 11 is a schematic diagram of an embodiment of a downhole tool having an imaging device and an end work device for pressure testing the integrity of a juncture.

25

FIG. 12 is a schematic diagram of an embodiment of a downhole tool for

5 performing testing of a perforated zone.

FIG. 13 is a schematic diagram of an embodiment of a downhole tool having an imaging device and an end work device for performing rework operations in wellbores.

10

FIG. 14 is a schematic diagram of an alternative embodiment of a downhole tool according to the present invention for performing cementing, fracturing and squeeze-off operations in wellbores.

15 FIGS. 15-16 are schematic diagrams of embodiments of a downhole tool for performing fishing operations in wellbores.

FIG. 17 is a schematic functional block diagram relating to the general operation of the downhole imaging and servicing tools of the present invention.

20

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. 1 is a schematic diagram of a system 100 for use in oilfield wellbores for imaging a work site, communicating data about the image to the surface and performing a desired operation (endwork) at the work site during a single trip in the wellbore. The system 100 includes a downhole service tool

25

5 **200** (also referred to herein as the downhole tool or the service tool) conveyed from a platform **11** of a rig **12** into a wellbore **22** by a suitable conveying device **24** from a source **66** thereof, such as a reel, being operated by a prime mover **68**. As an example, and not as any limitation, **FIG. 1** shows the conveying device **24** to be a coiled-tubing. Other conveying methods, such as wireline or
10 robotics devices may also be utilized. The upper end **202** of the service tool is connected to the tubing **24** via a suitable connector **204**. During operations, a drilling fluid from a source thereof **60** may be supplied to the wellbore **22** by a pump **68**.

15 A surface control unit **70** placed at a suitable location on the rig platform **11** preferably controls the operation of the system **100**. The control unit **70** includes a suitable computer and memory for processing data, providing selected information to an operator on a display **72**, including images of the work site, logs during tripping of the wellbore, location (depth) of the tool **200**
20 in the wellbore and orientation of the various elements of the service tool **200** in the wellbore **22** and values of selected tool, formation and wellbore parameters. The data from the service tool **200** may be transmitted to the surface by a suitable data link (telemetry) and recorded by a recorder **75** for later use. Suitable alarms **74**, coupled to the control unit **70**, are selectively
25 activated by the control unit **70** when certain operating parameters exceed their respective limits. The operation of control units, such as the control unit **70**,

5 is known and is, thus, not described in detail herein.

The service tool 200 includes one or more imaging devices or image sensors 210 for imaging work sites downhole, one or more end work devices 212a-212b, one or more control mechanisms (hydraulic or electro-mechanical) 214 for controlling the operation of the end work devices 212a-212b and/or the imaging devices 210. The tool 200 may also include other sensors and devices, generally denoted herein by numeral 216, for determining desired parameters or characteristics relating to the tool 200 and the wellbore 22. Such sensors and devices may include devices for measuring temperature and pressure inside the tool 200 and in the wellbore 22, sensors for determining the depth of the tool in the wellbore 22, position (x, y, and z coordinates) of the tool 200, inclinometer for determining the inclination of the tool 200 in the wellbore 22, gyroscopic devices, accelerometers, devices for determining the pull force, center line position, gripping force, tool configuration and devices for determining the flow of fluids downhole.

The tool 200 further may include one or more formation evaluation tools for determining the characteristics of the formation surrounding the tool in the wellbore. Such devices may include gamma ray devices and devices for determining the formation resistivity. The tool 200 may include devices for determining the wellbore inner dimensions, such as calipers, casing collar

5 locator devices for locating the casing joints and determining and correlating tool
200 depth in the wellbore 22, casing inspection devices for determining the
condition of the casing, such as casing 16 for pits and fractures. The formation
evaluation sensors, depth measuring devices, casing collar locator devices and
the inspection devices may be used to log the wellbore while tripping into and
10 or out of the wellbore 22.

The service tool 200 preferably includes a central electronic and data
processing unit or downhole control unit or circuit 218 for receiving signals and
data from downhole devices, processing such data, communicating with the
15 surface control unit 70 and for controlling the operations of the downhole
devices. The control unit 218 preferably includes one or more processors
(micro-controllers or micro-processors) for performing data manipulation
according to programmed instructions provided thereto from the surface or
stored in memory in the downhole tool 200.

20

The service tool 200 preferably includes a two-way telemetry 220 that
includes a transmitter for receiving data including the image data, from the
control unit 218, downhole sensors and devices and transmits signals
representative of such data to the surface control unit 70. Any suitable
25 transmitter may be utilized for the purpose of this invention including an electro-
magnetic transmitter, a fluid acoustic transmitter, a tubular fluid transmitter, a

5 mud pulse transmitter, a fiber optics device and a conductor. The telemetry system 220 also includes a receiver which receives signals transmitted from the surface control unit 70 to the tool 200. The receiver communicates such received signals to the various devices in the tool via the control unit 218 as explained later in reference to FIG. 17.

10

Still referring to FIG 1, the imaging sensor or device 210 may be any suitable sensor including a camera for optical viewing, microwave device, contact device (tactile device), such as a probe or a rotary device, an acoustic device, ultrasonic device, infra-red device, or RF device. The imaging sensor

15 210 may be a non-contacting device, such as an ultrasonic device, or a contacting device that has one or a series of projections from the tool 200 that engage with the wellbore and objects in the wellbore. If the quality or resolution of the image of the work site provided by the imaging device 210 depends, at least in part, on the frequency of the transmitted signal by the

20 imaging device 210, then it is preferred to adapt the device to sweep the frequency in a predetermined range of frequencies to determine an effective frequency and then obtain the image at such effective frequency. The imaging sensor 210 may be employed to provide a still or motion picture of a work site or an object downhole, or to determine the general shape of the object or the

25 work site or to distinguish certain features of the work site prior to, during and/or after the desired operation has been performed at the work site.

5 Still referring to FIG. 1, the end work devices 212a and 212b may include any device for performing a desired operation at the work site in the wellbore. The end work device 212a-212b may include a fishing tool adapted to grab a fish downhole, whipstock, diverter, re-entry tool, packer, seal, plug, perforating tool, fluid stimulation tool, fluid fracture tool, milling tool, cutting tool, drilling
10 tool, workover tool, testing tool, cementing tool, welding tool, an anchor, acidizing tool or inspection tool. As noted earlier, one or more end work devices 221a-212b may be included in the tool 200 for performing the desired operations at one or more work sites in the wellbore. Use of certain of these devices with an imaging sensor is described below as examples.

15 Additionally, the service tool 200 may include downhole controllable stabilizers 219a and 219b, each such stabilizer having a plurality of independently adjustable pad segments for providing lateral movement and lateral stability to the tool 200 and for anchoring the tool 200 in the wellbore 22. Such stabilizers are especially useful in deviated and horizontal wellbores.
20 A plurality of independently controlled outwardly extending arms 219c may be utilized to provide lateral movement and stability to the tool 200 within the wellbore 22. For a majority of the downhole imaging and servicing applications the end work device utilized is designed for the specific application. In some applications, several end work devices may be incorporated into the service tool
25 200. To provide desired degrees of freedom for each of the end work devices 212a-212b and the imaging device 210, such devices are coupled to the tool

5 via knuckle joints, such as joints, 212a,' 212b' and 210a respectively. The movement of such knuckle joints is preferably controlled by the control unit 218. The degrees of freedom present in the tool 200 and the type of image sensor utilized preferably allow obtaining the image of any work site in the wellbore.

10

The service tool 200 is preferably modular in design, in that selected devices in the tool are individual modules that can be interconnected to each other to assemble the desired configuration of the tool 200. It is preferred to form the image device 210 and the end work devices 212a-212b as modules
15 so that they can be placed in any order in the tool 200. Also, each of the end work devices 212a-212b and the image device 210 have independent degrees of freedom so that the tool 200 and any of the devices can be positioned, maneuvered and oriented in the wellbore in substantially any desired manner to perform the desired downhole operations.

20

The service tool 200 may be conveyed into the wellbore by a wireline, a coiled-tubing, a drill pipe, a downhole thruster or locomotive for pushing the tool 200 into a horizontal wellbore or a robotics device on the tool to move and guide the service tool in the wellbore.

25

As shown in FIG. 1A, the end work device 212' or any other device in

5 the tool 220 may have independently controlled downhole movements, such as shown by the solid lines 212' a and dotted lines 212' b, which allow the device 212' to be positioned at any angle in the wellbore 22. Thus, the service tool 200 can be positioned adjacent to a work site in a wellbore, image the work site, communicate such images online to the surface, perform the desired work
10 at the work site, and confirm the work performed during a single trip into the wellbore.

As noted-above, the system 100 may utilize any number of different imaging devices and end work devices. A number of such tool combinations are
15 described below. Prior to describing such tools, a novel cutting and milling device and imaging sensors are first described while referring to FIGS. 2-4.

FIG. 2 shows a schematic diagram of the system utilizing a novel high pressure fluid cutting device or tool 20 for cutting and milling materials in the
20 wellbore 22 according to one embodiment of the present invention. In general, the cutting tool includes a cutting element such as a nozzle, for discharging a relatively high pressure fluid to cut the member. A source of supplying the high pressure fluid in the downhole tool provides the high pressure fluid to the cutting element. The cutting element may be continuously positioned and
25 oriented at the desired location about the member to be cut by a control circuit contained in the downhole tool and/or at the surface.

5 The cutting tool 20 has a tubular housing (body) 26, which is adapted for connection with the conveying device 24 via a suitable connector 202. The housing 26 contains the various elements of the cutting tool 20, which include a cutting element section 28, a power section 34 for supplying pressurized fluid to the cutting element section 28, a control unit 36 which controls the vertical and radial position of the control element 28 and a downhole control unit 38 for housing the circuits and memories associated with the downhole tool 20.

10 The bottom section 28 of the housing 26 houses a cutting element 30 that terminates in a nozzle or probe 30a suitable for discharging a relatively high pressure fluid in the form of a jet stream of a relatively small cross-sectional area. For the majority of downhole cutting or milling applications, water discharged at a pressure greater than 60,000 psi is adequate in removing materials from within a wellbore. In cutting pipes, which are more than one-half inch thick, higher pressure may be required. The section 28 preferably rotates about the joint 32, which connects the section 28 with a hydraulic power section, generally denoted herein by numeral 34.

15 The power section 34 preferably includes a plurality of serial sections P_1 - P_n , each of which increases the pressure of a fluid above the pressure of the preceding section by a predetermines amount. The last section P_n discharges the fluid into the cutting element 30 at the desired pressure. The power section

5 **34** also may contain a device **33** which pulses the fluid at a predetermined rate before it is supplied to the cutting element **30**. High pressure pulsed jet stream is generally more effective in cutting materials than non-pulsed jet streams. The cutting element **30** may be a telescopic member that is moved along the tool's longitudinal axis z-z (axially) within the section **28** which enables positioning the
10 probe **30a** at the desired depth adjacent to the wellbore. In an alternative embodiment, the section **28** may be fixed while the nozzle **30** may be rotated radially about the tool longitudinal axis. The above described movements of the cutting element **30** provide multiple degrees of freedom, i.e., along the axial and radial direction thereby allowing accurate positioning of the nozzle **30** at any
15 desired location within the wellbore.

A section **36** contains devices for orienting the nozzle tip **30a** at the desired position. The cutting element section **28** is rotated about the wellbore axis to radially position the nozzle tip **32a**. The cutting element **30** is moved
20 axially to position the nozzle tip **30a** along the wellbore axis z-z. Hydraulically operated devices or electric motors are preferably utilized for performing such functions. The section **36** also preferably includes sensors for providing information about the tool inclination, nozzle position relative to the material to be cut and relative to one or more known reference points in the tool. Such
25 sensors, however, may be placed at any other desired locations in the tool **20**. In the configuration shown in FIG. 2, the cutting element **30** can cut materials

5 along the wellbore interior, which may include the casing or an area around a junction between the wellbore 22 (main wellbore) and a branch wellbore, as shown in FIG. 4. To cut the casing 23, the cutting element 30a is positioned at a desired location. As the tool 20 starts to cut the casing 23, it is rotated to circumferentially cut the pipe. If concentric casings are present, the fluid
10 pressure may be increased accordingly to cut concentric pipes.

FIG. 2A shows a configuration of a cutting element 30' that may be utilized to cut materials below the cutting tool 20. In this configuration, the probe 30a' discharges the fluid downhole of the tool 20. Arrows A-A indicate
15 that the cutting element 30' may be moved radially while the circular motion defined by arrows B-B indicates that the cutting element 30' may be moved along a circular path within the section 28'. The cutting element configuration shown in FIG. 2A is useful for performing reaming operations in a tubular member, such as a production tubing, which are required when interior of such
20 tubing is lined with sediments.

To remove a permanent packer difficult to remove, it is desirable to remove (cut away) only the packing elements and the associated anchors, if any, which typically lie between a packer body and the wellbore interior. The
25 packers and anchors typically engage the casing at areas that are relatively smaller than the tool body. Prior art tools typically cut through the entire

5 packer, which can take excessive time. The packers can readily be removed by only cutting the packing elements and any associated anchors disposed between the packer and the casing. In such applications, the cutting nozzle needs to be positioned over the packing element alone. FIGS. 2B-C show a configuration of the cutting element 30" whose nozzle 30a" may be placed at
10 any desired location above a packing element within the wellbore and then rotated to cut through the such element below the nozzle. Arrows C-C indicate that the probe 30a" may be moved radially within the section 28" while circular path defined by arrows D-D indicate that the cutting element may be rotated within the wellbore. FIG. 2C shows the position of the cutting element 30" after it has been moved radially a predetermined distance. As is seen in FIG. 2C, the nozzle tip 30a" extends beyond the section 28" which will allow the
15 tool 20 to cut a material anywhere below the tool 20.

Electrical circuits and downhole power supplies for operating and
20 controlling the operation of the cutting element 30, the power unit 34, and the devices and sensors placed in section 34 are preferably placed in a common electrical circuit section 38. Electrical connections between the electrical circuit section 38 and other elements are provided through suitable wires and connectors. The surface control unit 70 preferably controls the operation of the
25 cutting system 10.

5 The operation of the cutting system 10 will now be described with respect to cutting a section or window in a casing while referring to FIGS. 2 and 3. The tool 20 is conveyed downhole and positioned such that the nozzle is adjacent the section to be cut. The stabilizers 40a-b are set to ensure minimal radial movement of the tool 20 in the wellbore 22. A cutting profile 80 (FIG. 10 3) defining the coordinates for the outline of the section to be cut is stored in a memory (not shown) associated with the system 10. Such memory may be in the downhole circuit 36 or in the surface control unit 70. An example of such outline is shown in FIG. 3. The arrows 82 define the vectors associated with the profile 80. The profile 80 is preferably displayed on the monitor 72 at 15 the surface. An operator orients the nozzle tip 30a at a location within the section of the casing to be cut. The desired values of the fluid pressure and the pulse rate are input into the surface control unit 70 by a suitable means. The tool 20 is then activated to generate the required pressure and the pulse rate. The fluid to the tool 20 is preferably provided from the surface via the tubing 20 24. Alternatively, the wellbore fluid may be used.

 If the section to be cut is such that it will remain in position after it has been cut, perhaps due to the presence of a cement bond, or if the cut section can be dropped to the wellbore bottom as debris, then the system 10 may be 25 set so that the nozzle tip 30a will follow the profile 80, either by manual control by the operator or due to the use of a computer model or program in the

5 system. If the section must be cut into small pieces or cutting so that they may be transported to the surface, the cutting element is moved within the profile at a predetermined speed along a predetermined pattern, such as a matrix. This method ensures that the casing section will be cut into pieces that are small enough to be transported to the surface by circulating a fluid through the wellbore. During operations, the downhole circuits contained in the section 38 communicate with the surface control unit 70 via a two-way telemetry. The downhole telemetry is preferably contained in a section 39.

FIG. 4 shows the downhole cutting tool of FIG. 2 with an imaging device 15 90 attached below the cutting section 28. Any suitable imaging device may be utilized. The imaging device 90 is utilized to confirm the shape of the section of the casing or the junction after the cutting operation has been performed. The imaging device 90 may also be utilized to image the area to be cut to generate the desired cutting profile and then to confirm the cut profile after the 20 cutting operation. This enables the imaging of a location at a work site of interest and the performance of desired operation at the work site in a preexisting wellbore. Other types of downhole service tools may be utilized for imaging a location in a wellbore at which a tool operation is to be performed and performing the desired tool operation at the work site without retrieving the tool 25 from the wellbore. Certain downhole end work devices are described later.

5 **FIGS. 5A-5C** show embodiments of downhole ultrasonic imaging devices for use with an end work device to image a work site of interest and to perform a desired operation at the work site during a single trip into the wellbore.

FIG 5A shows a downhole service tool **250** having an end work device
10 **252** for performing a desired operation downhole, an ultrasonic device **260** (ultrasonic imaging sensor) placed downhole of the end work device **252** for imaging a work site or an object in the wellbore. The imaging device **260** has a number of sensor elements **264** arranged on a body. Each sensor element **264** acts as a transmitter and receiver. The preferred frequency range is between
15 100 KHz and 500 KHz. The ultrasonic transmitter is preferably adapted to sweep the frequency within a predetermined range of frequencies. The signals transmitted by the sensor element **264** are reflected back from the work site or the object and the reflected signals are received by the sensor elements **264**, which are processed by the control unit **256** or circuit in the tool **250** and
20 transmitted uphole via telemetry **258** to provide an image of the work site.

 The ultrasonic sensor **260** may be rotated or beam steered (i.e. electrically rotating or directing) to scan the inside of the wellbore. The ultrasonic signals are transmitted at a predetermined rate and the reflected
25 signals are received by the sensor elements **264** between successive firings of the transmitter. The end work device **252** may include a work element **253**

5 that may be rotated by device 254 along the arrows 252a to orient the work element radially and may be moved vertically as shown by the arrows 252b, i.e., longitudinally to move the work element 253 uphole or downhole, which enables positioning the work element at any desired location in the wellbore. The sensor 260 and the end work device 252 are independently rotatable. The
10 sensor 260 may be disposed above the end work device 252.

As shown in the tool 250' of FIG. 5B, the sensor elements 264' may be arranged on the body 255 of the end work device 252' around the end work element 253'. The sensor elements 264' may be disposed in any desired
15 manner to image a segment of the wellbore or the entire wellbore interior. The tool may be moved along the directions denoted by arrows 252a' and 252b'. The vertical length of the sensor elements 264' and the spacing there between defines the vertical imaging sweep and the resolution. Similarly, the horizontal distance of the sensor elements 264' and the spacing between the sensor
20 elements defines the radial sweep and the resolution. Alternatively, sensor elements may be arranged on the tool to direct signals downhole, as shown in FIG. 5C here the sensor elements 264" are disposed at the downhole (bottom) end of a service tool 250". This enables the service tool 250" to image an object or a work site downhole of the service tool 250".

25

FIG. 5D shows the downhole service tool 250, shown in FIG. 5A,

5 positioned adjacent to a juncture 304 between a main wellbore 300 and a branch or lateral wellbore 302. The tool 250 may be utilized to image the juncture 304 and perform an operation thereat. The tool 250 provides an image of the juncture 304 to the surface prior to performing an operation. The image may be utilized to position the tool 250 at the desired location and to
10 appropriately orient the tool 250 adjacent the juncture 304 . The desired operation may then be performed at the juncture 304, which may include a window cutting operation, reaming operation, cementing, welding, sealing or any other desired operation.

15 FIG. 6A shows a schematic diagram of a system 710 for obtaining still and/or video images of a wellbore interior or an object in the wellbore. The system 710 includes a downhole tool 720 that contains a camera for taking pictures of the work site and a mechanism for displacing the non-transparent fluid around the work site with a transparent or substantially transparent fluid.
20 For convenience and ease of explanation and understanding, and not as a limitation system 710 shows only the imaging device, i.e. without any end work device.

The system 710 includes a downhole imaging tool 720 conveyed from
25 a platform 11 of a derrick 12 into a wellbore 122 by a suitable conveying device 124, such as a tubing or wireline. The imaging tool 720 has a tubular housing

5 **726**, which is adapted for connection with the conveying device **724** via a suitable connector **719**. The housing **726** contains the various elements of imaging tool **720**. The bottom section of the housing **726** contains a camera section **728**, which houses a retractable camera **730**. The camera **730** may be moved within a camera housing **732** by a hydraulic means or an electric means, such as motor, generally denoted herein by numeral **734**. The electrical circuits and downhole power supplies for operating and controlling the camera movements are preferably placed in a common electrical circuit section **736**. Electrical connections between the camera section **728** and the electrical circuit section **736** are provided through suitable wires and connectors between the two sections. The camera **730** in its retracted position, as shown by the solid lines **730**, may be sealed from the outside environment by closing a hatch or door **738**. The hatch may be adapted to open outward as shown by the dotted line **738a** or by a sliding door (not shown). In the fully retracted position, the camera **730** resides completely inside the housing **728** so that the hatch **738** may be closed to seal the camera **730** from the outside environment.

In the fully extended position, the camera **730** extends far enough from the camera section **728** or any other obstruction, as shown by the dotted line **730a**, so that the camera **730** can be rotated 360 degrees and can take unobstructed pictures of its surroundings. A light source **740** attached near the camera provides sufficient light for the camera to obtain pictures downhole.

5 Additional light sources (not shown) may be provided on the tool body 726 to provide light in all the directions. The camera 730 may be focused downward as shown in FIG. 6A or horizontally as shown in FIG. 6B or along any other desired direction depending upon the intended application.

10 The imaging tool 720 contains a fluid injection section 744 for injecting a substantially transparent fluid (herein referred to as the clear fluid) into the wellbore. The fluid injection section 744 is preferably placed above (uphole) the camera section 728. The fluid injection section 744 includes one or more chambers, such as 746a and 746b, for storing therein the clear fluid. A pump
15 746 in the section 744 is used to controllably inject the clear fluid from the chambers 746a-746b into the wellbore below the camera section 728 via a fluid line 748. The fluid line 748 runs from the fluid injection section 744 through the camera section 728 to an outlet point 748a below the camera section 728. Any downhole electrical control circuits and related power supplies for operating
20 the pump 746 are preferably housed in the electrical section 736.

A surface control unit 770 placed at a suitable location on the rig platform 711 preferably controls the operation of the imaging system 710. The control unit 770 includes a suitable computer, associated memory, a recorder
25 for recording data and a display or monitor 772. The operation of control units, such as the control unit 770, is known and is, thus, not described in detail

5 herein.

The operation of the imaging system 710 will now be described in reference to obtaining an image of an object, such as object 750, stuck in the wellbore 722. To obtain the image of the object 750, the location of the object
10 is first determined. A number of techniques have been utilized in the oilfield applications for determining the location of an object or work site in a wellbore. Any such technique or method may be utilized for determining the location of the object 750 for the purposes of this invention. The tool 720 is then conveyed into the wellbore 722 until the bottom end 752a of the fluid return
15 pipe 752 is below the surface 750a of the object 750 that is to be imaged. The packer 733 is then inflated or set in the wellbore 722 to seal the wellbore section 722a below the camera section 728 from the wellbore section 722b above the packer 733. The pump 746 is then activated from the surface control unit 770 to inject the clear fluid from the chambers 746a-b into the
20 wellbore section 722a via fluid line 748. The injection of the clear fluid into the section 722a causes the wellbore fluid present in the section 722a to enter the fluid pipe 752, which fluid is discharged into the wellbore section 722b above the packer 733 via a port 752b. This processes is continued until the wellbore fluid between the port 752a and the camera section 728 has been replaced with
25 the clear fluid. The clear fluid chosen is preferably lighter than the wellbore fluid and will not mix with the wellbore fluid. Such a clear fluid when injected into

5 the wellbore section 722a will uniformly displace the wellbore fluid. In some applications, it may be necessary to continue to inject additional clear fluid so as to completely flush out the wellbore fluid from section 722a. The system of the present invention may employ a clear fluid source at the surface (not shown) instead of downhole chambers. In this embodiment, the clear fluid is
10 continuously supplied to the chamber 746 from a surface source via a line placed in the conveying means 724. Such a system may be necessary when large quantities of clear fluid are required to flush out the wellbore fluid.

After the object 750 has been exposed to the clear fluid, the camera door
15 738 is opened and the camera 730 is lowered to its fully extended position 730a. To obtain the images of the object 750, the camera lights 740 are activated, the camera 730 is oriented in a desired position and the camera is operated to obtain images of the object 750. The images from the camera are transmitted by the downhole control circuits in section 736 to the surface
20 control unit 770 via a two-way telemetry 725. The images are displayed on the monitor 772. The operator can orient the camera in any desired direction and continue to obtain images. If a video camera is used, the motion pictures are displayed on the monitor. The images are recorded in the recorder associated with the surface control unit 770.

25

FIG. 6B shows the application of the imaging system 710 described

5 above in reference to **FIG. 5D** for obtaining images of a junction **760** between
a main wellbore **722** and a branch wellbore **723**. To obtain images of the
junction **760**, a packer **735** is first set in the wellbore **722** below the junction
760 to completely seal off the wellbore section **22c** lying below the packer **35**.
The imaging tool **720** is then conveyed in the wellbore **722** so that the packer
10 **33** is completely above the junction **760** while the port **752a** of the fluid return
line **752** is below the junction **760**. The imaging tool **720** is operated as
described earlier to displace the wellbore fluid in the wellbore section **722a'**
between the packers **733** and **735** with the clear fluid. The camera **730** is then
oriented in the direction of the junction **760** to obtain the desired images.
15 Images of other objects in the wellbore and any section of the wellbore may be
obtained by the imaging system **710** in the above-described manner.

FIG. 6C shows another embodiment of a downhole imaging tool **800**.
The imaging tool **800** includes a flexible inflatable device **810** at a lower end
20 of the tool **800**. A fluid injection system **812** in the tool **800** injects a fluid into
the device **810**, thereby inflating the device **810**. The fluid injection system
812 preferably contains a fluid pump section **814** having a reversible pump
therein for injecting or pumping a fluid from a chamber **816** into the device **810**
and vice versa.

25

FIG. 6D shows a cross section of the flexible inflatable device **810**. It

5 includes a bladder **840** made from a flexible material, such as rubber. A plurality of sensors **842** are arranged along the inner surface **840a** of the bladder **840** in a matrix or grid as shown in **FIG. 6D**. Each such sensor provides a signal corresponding to the deformation of the bladder surface to which the sensor is attached from a predetermined norm. The signals from each such

10 sensor are transmitted to a downhole control circuit **816** via a conductor **844** and communication link **848**. Fluid line **846** provides access to the bladder inside **840a**. The downhole control circuit **816** controls the operation of the pump section **812**, receives data or signals from the each of the sensors **842**, conditions the signals and may manipulate the signals to obtain an image. The

15 downhole control circuit **816** may transmit the conditioned signals to a surface control unit, such as unit **970** shown in **FIG. 17**, which produces the image based on a model stored in the control unit. The model is predetermined or predefined based on the geometry of the flexible member **810** and the configuration of the sensors **842**. The model is stored in a downhole memory

20 associated with the downhole control circuit **816** when the system is designed to compute the model downhole.

Operation of the tool **800** will now be described in the context of obtaining an image of a junction between the main wellbore **822** and the branch

25 wellbore **823**. To obtain an image of the junction **860**, the tool **800** is conveyed into the main wellbore **822** until the flexible member is adjacent to the

5 junction **860**. The fluid from the fluid section **812** is then injected into the flexible member **810**, thereby inflating the member **810**. A portion of the flexible member at the junction **860** attains the shape that corresponds to the junction **860** outline. The downhole control circuit **816** measures the signals from each of the sensors **842** and processes such signals as described above
10 to obtain the image of the junction. Image of an object in the wellbore, such as object **850** shown in FIG. 6B, is obtained by inflating the flexible member **810** while urging it against the object.

FIGS. 7 - 16 show embodiments of certain downhole tools which are
15 adapted to image a work site of interest and perform a desired operation at work sites in a pre-existing wellbores during a single trip according to the present invention.

FIG. 7 shows an embodiment of a downhole service tool **350** conveyable
20 by a tubular member **356**, such as a drill pipe. The end work device **352** is a milling device and is disposed at the bottom end of the conveying member **356**. A suitable imaging device **354** is disposed above the milling device **352**. A conduit **358** may be utilized to supply hydraulic or electric power to the tool **350**. A control unit, other sensors, and associated electronic circuitry and
25 telemetry may be disposed in the tool **350** as described earlier. During operation, the work site or the object to be milled is imaged by the imaging

5 sensor 354 and the cutting operation is performed by the milling device 352.

Images of the area being cut are periodically obtained to ensure that the cutting operation is being performed correctly. Other end work devices, such as tools for determining the widow seal integrity may be disposed with the milling device 352.

10

FIG. 8A shows a downhole service tool 370 that may be utilized to image a location in the wellbore 375 and then drill the lateral wellbore 377 and/or to facilitate re-entry of an end work device into the lateral wellbore 377. To drill the lateral wellbore 377, the tool 370 is positioned above a whipstock or any
15 other suitable re-entry device 379. An image device 380 provides images of the location where the lateral wellbore 377 will be drilled, which image may be utilized to position and orient the drilling element (bit) 372. Alternatively, since the image is available, the operator can set kick-off devices 382 to cause the device 372 to perform an operation at a juncture 377a without first requiring
20 the installation of the re-entry device 379, thereby avoiding another trip downhole. The tool 370 may similarly be used to reenter the wellbore 377 to perform secondary operations in the branch wellbore 377, thereby eliminating an extra trip to install the re-entry device 379.

25 FIGS. 8B and 8C show another embodiment of a downhole service tool 385 which can be utilized to enter a branch wellbore 377 from a main wellbore

5 **375** without the use of a re-entry device, such as a whipstock or a diverter.

The downhole service tool **385** includes an end work device **386** at the service tool **385** downhole end, a suitable imaging device **387** and a downhole operated tool orientation device **388**. The device **388** preferably is a hydraulically or electrically operated knuckle-type joint which bends the tool **385** portions above and below the device **388** up to a predetermined maximum angle. The service tool **388** is lowered into the main wellbore **375** to a known distance above the juncture **377a**. The image device **387** provides images of the juncture **377a**. The operator then orients the tool **385** and activates the device **388** to bend the tool **385** at a predetermined angle. The device is locked into the bent position and the tool **385** continues to be lowered into the wellbore. Inserting the tool **385** further causes it to enter into the branch wellbore **377** as shown in FIG. 8C.

Once the bottom end device **386** has entered into the branch wellbore **377**, the device **388** is unlocked, which allows the front portion of the tool **385** to straighten as it moves further into the branch wellbore **377**. After the tool **385** has been conveyed to the desired work site in the branch wellbore **377**, the end work device **386** is then utilized to perform the desired operation. Thus, the service tool configuration of FIGS. 8B-8C allows the operator to (a) convey the service tool **385** into a branch or lateral wellbore **377** without the use of a secondary device, such as a diverter, and (b) image a desired work site in the

5 branch wellbore and perform a desired operation at the work site in a single trip.

This service tool 385 can eliminate two downhole trips, one to install a diverter, such as the diverter 379 shown in FIG. 8 and a second trip to image the work site prior to performing the work at the work site.

10 FIG. 8D shows an alternative device 390 for causing the service tool 385 to enter the branch wellbore without the use of a diverter. The device 390 includes a plurality of arms or members which can be independently extended outward from the service tool body to urge against the wellbore wall 375a. Selectively urging the members 392 against the wellbore wall 375a causes the
15 tool to enter the branch wellbore 377.

The knuckle-joint 388 shown in FIG. 8B and the arm members 392 shown in FIG. 8D are operated by their respective control units in the service tool 385. The downhole control unit (FIG. 1) controls the operation of these
20 devices based on instructions provided from the surface control unit 70 or downhole stored programmed instructions. The service tool may also be programmed to locate the juncture 377a and cause the tool 385 to enter the branch wellbore 377. Thus, the service tool shown in FIGS. 8B-8C can locate a lateral or multilateral juncture, adjust or orient itself and penetrate the lateral
25 wellbore without the use of additional devices, such as diverters and whipstocks, and thereafter perform an end work in the lateral wellbore during

5 a single trip downhole.

FIG. 9 shows an embodiment of a service tool 400 with an imaging device 420 and a packer 410 as the end work device. The service tool 400 is shown conveyed by a tubular 402 into an open hole 404. The packer 410 has an inflatable packer element 412, which when inflated seals an annulus between the packer 410 and the wellbore 404. The packer 410 is attached to the tubular 402 by a shear bolt 406 having a weak point 406a that may be sheared to separate the packer 410 from the tubular 402. An imaging device 420 for imaging the annulus 407 between the packer 410 and the wellbore 404 is placed above the shear point 406a.

To set the packer element 412 in the annulus 407, the tool 400 is positioned in the wellbore 404 so that the packer 410 is across from the area 407. The packer 410 is set by injecting a hardening fluid, such as cement, epoxy, or another suitable material, into the packer element 412. If an acoustic device is used as the imaging device, its response characteristics are a function of the manner the annulus is being enclosed with the hardening material. The data from the imaging device 420 is analyzed to determine the quality of the bond between the packer element 412 and the formation 404. Based on the imaging characteristics, the amount of the hardening material being supplied to the packer element 412 can be adjusted to improve the integrity of the seal.

5 After the packer 410 has been set, the bolt 406 is sheared to retrieve the service tool 400 from the wellbore 404.

FIGS. 10A and 10B show examples of embodiments of downhole service tools for imaging a work site of interest and performing welding operations at the work site during a single trip in the wellbore. FIG. 10A shows the service tool 450 for welding a juncture 434 between a casing 430 in a main wellbore 435 and a casing 432 in a branch or lateral wellbore 437. The service tool 450 includes a welding device 452 at its bottomhole end. The service tool 450 may also include a milling device 456 to dress or smooth any rough welding performed by the welding device 452. An image device 458 is preferably placed above the welding device 452 and the milling device 456. The welding device 452 is coupled in the tool 450 with a rotatable joint 453. Similarly, if a milling device 456 is utilized, it is preferably disposed in the service tool 450 via rotatable joints 455a and 455b. The rotatable joints 453, and 455a and 455b allow the welding device 452 and the milling device 456 to independently rotate in the wellbore 435. The service tool 450 also includes a control unit 461 to position and orient the tool 450 in the casing 430 and other desired devices 462. A central processor 460 processes signals and data from the downhole devices and communicates with the surface computer 70 (FIG. 1) via a two-way telemetry 464.

5 To weld the casings 430 and 432 at the juncture 434, the service tool 450 is conveyed into the casing 430 by a suitable conveying system 451. The imaging device 456 provides an image of the juncture 434 to the surface control unit 70 (FIG. 1). The welding device 452 is positioned adjacent to the juncture 434. The welding tip or probe 454, having its own degrees of freedom, is positioned at the juncture to perform the welding operation. The probe 454 may be extended radially and/or axially to position the probe 454 at any desired location in the casing 430. The axial movement of the service tool 450, rotary movement of the joint 453 and the axial and radial movements of the probe 454 provide necessary degrees of freedom of movement to position the welding probe 454 at any desired spot in the casing 430. One or more downhole-controlled and independently-operated stabilizers or radially extendable arms 466 or any other suitable device may be utilized to urge the probe 454 against the juncture 434 to be welded.

20 The image device 456 may be utilized to image the juncture 434 after welding operations or intermittently during welding operations to ensure quality and integrity of the welds 434a. The tool 450 may then be repositioned to place the milling device 456 adjacent to the weld 434a. The milling device 456 has a milling surface 456a on its outside, which is extended outwardly and urged against the weld 434a to smooth out the weld 434a. Any suitable milling device, including any commercially available mechanical milling device may be

5 utilized in the service tool 450.

FIG. 10B shows a manner of utilizing the service tool 450 for welding a device 470, such as a permanent packer, a plug, or a plate below the plate inside a casing 475. To weld the device 470 inside the casing 475, the service tool 450 is placed above the device 470 to image the work site 471 to be welded. The tool 450 is then repositioned to place the welding probe 454 against the area 471. The welding operation is then performed in the manner described above. It should be noted that only one type of welding device has been described above to perform selected welding operations to describe the concept of the invention. Any other suitable welding device may be utilized with the service tool 450 to perform any type of welding operations.

FIGS. 11 and 12 show a service tool 500 for performing testing operations in the wellbore. FIG. 11 shows a configuration for testing the integrity of a seal. In the example of FIG. 11, a seal 514 is placed in a lateral wellbore 512 formed from a main wellbore 510. The service tool 500 is shown conveyed into the main wellbore 510. It includes a suitable imaging device 502, a device 504 for discharging a high pressure fluid into the wellbore 510 and a pair of packers 506a and 506b spaced apart on the service tool 500 to seal a zone of interest 518 in the wellbore 510. To test the integrity of the seal 514, the service tool 500 is positioned adjacent to a juncture 515 to provide an

5 image of the juncture 515, which image is utilized to position the tool 500 such that the upper packer 506a is above the juncture 515 and the lower packer 506b is below the juncture 515. The packers 506a-506b are then set as shown in FIG. 11 to seal the space 518 enclosed by the seal 514, the upper packer 506a and the lower packer 506b. Pressurized fluid is then discharged
10 from the device 504 into the space 518 via openings 504a. The pressure drop, if any, in the space 518 is measured over a predetermined time period, which provides an indication of the seal integrity.

FIG. 12 shows a configuration of a service tool 520 for use in testing a
15 production zone or reservoir 525. This configuration is substantially similar to the tool configuration shown in FIG. 11. FIG. 12 shows a cased hole 540 having a production zone 539. The casing 530 has a plurality of perforations 532 through which fluids from the reservoir 525 enter into the casing 530 at zone 539. Periodic testing of production zones is commonly performed during
20 the life of such production zones to determine the fluid flow from each zone or a portion thereof, to build and update reservoir models and to estimate the future production from such reservoirs. To test a production zone, such as zone 539, the tool 520 images the perforated zone 542 (work site). The image is utilized, among other things, to position the tool 520 adjacent to the
25 perforations 532. The packers 526a and 526b are set in the casing 530 to seal the zone 539 between the packers 526a-526b. A testing device 524 is then

5 utilized to perform desired testing. The testing device 524 shown has a flow control valve 524a to control the fluid flow from the reservoir into the tool 530. The received fluid may be collected in chambers 527 for further analysis or discharged into the wellbore uphole of the upper packer 526a. The testing device 524 also may include temperature sensors, pressure sensors and may

10 include devices to determine chemical and/or physical properties of the fluids, including specific gravity, oil, gas and water content in the formation fluid. To determine pressure and temperature build up, commonly performed for reservoir modeling, the valve 524 is closed and required measurements are made over a predetermined time period. Any other type of testing device may also be

15 employed in addition to or as an alternative to the device 424. The image obtained of the perforated zone 539 allows an operator to position the tool 530 precisely adjacent to the desired perforations 532. The packers 526a and 526b may be made slidable over the tool 530 so that the length of the zone 539 may be adjusted downhole.

20

It will be obvious that FIGS. 11 and 12 show specific examples in which the service tool of the present invention can be utilized to image a work site in a wellbore and then perform testing (end work) during a single trip in the wellbore. Any other suitable testing device may be utilized for the purposes of

25 this invention.

5 **FIGS. 13 and 14** show examples of the service tool of the present invention for performing remedial work in preexisting wellbores. **FIG. 13** shows the service tool **550** conveyed in a cased wellbore **555** lined with a casing **556**. The casing **556** has a plurality of perforations **558** adjacent to a reservoir **560**. The service tool **550** includes a suitable image device **564** and a device or unit
10 **566** for injecting fluids under pressure into the wellbore **555**. The remedial work in the wellbore **555** may include injecting a fluid (water, sand, glass, chemicals or mixture of water and additives, etc.) under pressure through the perforations **558** to increase the flow of formation fluids from the reservoir **560** into the wellbore **555**. To perform such a remedial work, the service tool **550**
15 is positioned in the wellbore **555** to obtain images of the perforated zone **568**. The images are utilized to reposition the tool, if necessary. Packers **570a** and **570b** are set in place to isolate the desired zone of interest or the work site **568**. The desired fluid is then injected into the zone **568** by the device **566** via control valves **566a**. The desired fluid may be injected via tubing **557** from the
20 surface. The flow from each of the control valves **566a** is preferably independently controlled by a downhole control unit **571**. The above-described system is equally applicable for open hole fracturing applications.

 The service tool **550** shown in **FIG. 13** may also contain a test device,
25 such as the test device **572**, similar to the test device **534** shown in **FIG. 11** to perform testing of the zone **568** to determine the effectiveness of the work

5 performed. The service tool 550 shown in FIG. 13 thus may be utilized to image a work site (production zone 568), perform a work (remedial work) at the work site, and then determine the effectiveness of the work performed during a single trip in the wellbore.

10 During the life of a wellbore, it is sometimes desired or even required to seal off a production zone or a portion thereof for reasons such as the zone is producing excessive amounts of water and is impeding the flow of hydrocarbons from other production zones in the same wellbore. FIG. 14 shows a configuration of a service tool 580 of the present invention for sealing
15 a production zone 599 or a portion thereof by cementing the zone 599 and then confirming the integrity of the seal. FIG. 14 shows a service tool 580 conveyed in a cased wellbore 581 lined with a casing 582. The casing 582 has a plurality of perforations 584 adjacent to a reservoir 585. The service tool 580 includes a suitable image device 586 and a device or unit 588 for injecting cement slurry
20 under pressure into the wellbore 581. The remedial work in the wellbore 581 may include closing off a single perforation 584a or the zone 599 having a number of perforations 584. To close off the zone 599, the tool 580 is positioned in the wellbore 581 to obtain images of the perforated zone 599. The images are utilized to reposition the tool 580, if necessary, and packers
25 596a and 596b are set in place to isolate the desired zone of interest or the work site of interest 599. The cement is then injected from the cement device

5 **588** into the zone **599** via a control valve **592b** to seal the intended zone **599**.

The tool **580** is then retrieved. To cement a single perforation, such as perforation **584a**, a flexible cup **590** on the outside of the tool **580** is urged against the perforation **584a**. Cement or any other desired fluid is then controllably discharged from an opening **592a** to close the perforation **584a**.

10 The tool **580** may also include a testing device **594** to test the integrity of cementing work. The device **594** may be a flow measuring device to determine if any fluid is flowing out of the cemented zone. Pressure and temperature measuring devices and resistivity measuring devices may also be utilized as test devices. Additionally, the image device **586** may be utilized to obtain secondary
15 images of the cemented work site to determine the effectiveness of the work performed. It should be noted that the term cement is used to generally mean hardening materials, including cement slurry, epoxies and any other suitable material. In some cases, it is desirable to intentionally damage a formation or zone to seal unwanted production of formation fluids. The above-described
20 method may also be utilized for such applications.

FIGS. 15 and 16 show examples of service tools of the present invention for performing fishing operations preexisting wellbores. FIG. 15 shows a service tool **630** conveyed in a wellbore **632** by a tubing **633**. The service tool
25 **630** includes a suitable image device **635** having a retractable tactile sensor for imaging an object, such as a fish **640** stuck in the wellbore **632**. The tactile

5 image device 635 includes a retractable probe 637, which has a tip 639 that can scan the entire inside of the wellbore 632. The probe tip 639 attached to an arm 641 which can move radially and axially around a rotary joint 638. The joint 638 can move axially as shown by the dotted lines 643, thereby providing sufficient numbers of degrees of freedom to the probe tip 639 to scan the

10 wellbore 632. The service tool 630 includes a suitable fishing device for engaging the fish 640 and other devices, sensors, control circuits and telemetry, collectively designated by numeral 645. To retrieve the fish 640 from the wellbore 632, the service tool 630 is positioned above the fish 640. The imaging device 635 senses the location and profile of the fish 640, which is

15 communicated to the surface. The tool 630 is then repositioned, the fishing device 644 is activated to engage the fish 640. Any other suitable imaging device may be utilized for imaging the fish 640. Also any suitable fishing device may be utilized for the purpose of this invention. For example, the fishing device may be the type that grabs the fish from the outside or the inside of the

20 fish 640. It may be a spear type or an over-shot type device as described in U.S. Patent No. 5,242,201, which is incorporated herein by reference. The fishing tool 635 may drill into the fish 640 to securely engage the fish 640. The fish 640 is retrieved by retrieving the tool 630. It should be obvious that the tactile imaging device 635 may include more than one probes and that such

25 imaging devices may be utilized in any of the service tools made according to this invention.

5 **FIG. 16** shows the use of a service tool **650** conveyed in a wellbore **652** by a tubing **653**. The service tool **650** includes a suitable imaging device **660**, including an ultrasonic and tactile device. In the example of **FIG. 16** a fish **666** is shown stuck in a wash-out area **654** of the wellbore **652**. To retrieve the fish **666**, the tool **650** is positioned adjacent to the fish **666** to image the **666** fish by the imaging device **660**. The tool **650** may include a one or more knuckle devices **672** that can be activated from the surface or downhole control circuits **670** to position the image device **660** and a fishing device **664** in the wash-out region **654**. After the image is taken, the fishing device **664** is repositioned to engage the fish **666**. The fish **666** may be moved from the wash-out region **654** by reactivating the knuckle joints **672**. The fish **666** is retrieved by retrieving the tool **650**. It should be noted that any suitable imaging and fishing devices may be utilized for the purpose of this application. The fishing tools of this invention preferably have degrees of freedom of movement that are sufficient to position the tool to retrieve the fish at any place in the wellbore.

Thus far selected examples of the downhole service tool have been described above to illustrate the concepts of the present invention. It will, however, be understood that many other end work devices and imaging devices can be utilized to image an object and work site in a wellbore and to perform a desired operation at the work site without requiring retrieving the service tool

5 according to the concepts of this invention. For example, the service tool 200 (FIG. 1) of the present invention may be utilized to locate a weak point in the well casing, such as a crack or a pit, and perform welding. The service tool 200 may be utilized to perform swaging operations downhole or to inject polymers into the wellbore. Yet, in certain other applications, it is desirable to confirm

10 the engagement of a tool conveyed from the surface to downhole device prior to performing an operation with such tool. The service tool of the present invention may include an engagement device and a sensor for generating signals that differ when the tool is engaged with the downhole device and when it fully or properly engaged. The service tool may include without limitation any

15 desired engagement device, including a collet type device, a screw type device, a latching device that is designed to latch into or onto a receptacle associated with the downhole device, a cone type device, a device that is designed to mate with a matching profile in the downhole device, or a collet or a pressure activated device. To perform the desired operation, the service tool is placed

20 at a desired location in the wellbore and the sensor is activated to provide the tool response. The tool is engaged with the downhole device. The sensor continues to provide signals responsive to the engagement process. The response signature is utilized to confirm the engagement of the tool device with the downhole device.

25

Additionally, the service tool 200 may incorporate one or more robotics

5 devices that can remove a member or a sensor, install a sensor or a device, such as a fluid control valve, remove a liner, interchange parts, replace power sources, such as batteries, turbines, etc., inflate a device, manipulate a device or part downhole from its current position to a new position, such as a sliding sleeve from an open position to a closed position or vice versa, and perform any
10 other desired function. The image device in the service tool is preferably utilized to locate the part to be replaced, installed or manipulated.

It is often desirable to measure selected wellbore and formation parameters either prior to or after performing an end work. Frequently, such
15 information is obtained by logging the wellbore prior to performing the end work, which typically requires an extra trip downhole. The service tool of the present invention, such as tool 200 shown in FIG. 1 and other tools shown in FIGS. 2-16 may include one or more logging devices or sensors. For example, for the work to be performed in cased holes, such as shown in FIGS. 10a-14,
20 a collar locator may be incorporated in the service tool 200 to log the depth of the tool 200 while tripping downhole. Collar locators provide relatively precise measurements of the wellbore depth and can be utilized to correlate depth measurement made from surface instruments, such as wheel type devices. The collar locator depth measurements can be utilized to position and locate the
25 imaging and end work devices of the tool 200 in the wellbore. Also, casing inspection devices, such as eddy current devices or magnetic devices may be

5 utilized to determine the condition of the casing, such as pits and cracks. Similarly, a device to determine the cement bond between the casing and the formation may be incorporated to obtain a cement bond log during tripping downhole. Information about the cement bond quality and the casing condition are especially useful for wellbores which have been in production for a relatively
10 long time period or wells which produce high amounts of sour crude oil or gas. Additionally, resistivity measurement devices may be utilized to determine the presence of water in the wellbore or to obtain a log of the formation resistivity. Similarly gamma ray devices may be utilized measure background radiation. Other formation evaluation sensors may also be utilized to provide
15 corresponding logs while tripping into or out of the wellbore.

The description thus far substantially relates to a service tool which utilizes an image sensor and an end work device to image a work site in a wellbore and perform a selected end work. As described earlier, the service tool
20 of the present invention also provides confirmation about the quality and effectiveness of the end work performed downhole during the same trip. The general operation of the above-described tools is described by way of an example of a functional block diagram for use with the system of FIG. 1. Such methods and operations are equally applicable to the other downhole service
25 tools made according to the present invention. Such operations will now be described while referring to FIG. 17.

5 The downhole section of the control circuit 900 preferably includes a microprocessor-based downhole control circuit 910. The control circuit 910 determines the position and orientation of the tool as shown in box 912. A circuit 915 controls the operation of the downhole tool. The control circuit 910 also controls the end work devices, such as cutting tool 914a and any other end
10 work devices, generally designated herein by numeral 914n. During operations, the control circuit 910 receives information from other downhole devices and sensors, such as a depth indicator 918 and orientation devices, such as accelerometers and gyroscopes. The control unit 900 communicates with the surface control unit 970 via the downhole telemetry 939 and via a data or
15 communication link 939a. The control circuit 910 also preferably controls the operation of the downhole devices, such as the power unit 934, stabilizers and other desired downhole devices (not shown). The downhole control circuit 910 includes a memory 920 for storing therein data and programmed instructions. The surface control unit 970 preferably includes a computer 930, which
20 manipulates data, a recorder 932 for recording images and other data and an input device 934, such as a keyboard or a touch screen for inputting instructions and for displaying information on the monitor 972. The surface control unit 970 and the downhole tool communicate with each other via a suitable two-way telemetry system.

25

While the foregoing disclosure is directed to the preferred embodiments

5 of the invention, various modifications will be apparent to those skilled in the art. It is intended that all variations within the scope and spirit of the appended claims be embraced by the foregoing disclosure.

5 **WHAT IS CLAIMED IS:**

6

7 1. A downhole tool for imaging a work site within a pre-existing wellbore
8 and performing a tool operation at the work site during a single trip of the tool
9 in the wellbore, the tool comprising;

10 (a) an imaging device in the downhole tool for imaging the work site;

11 and

12 (c) a work device in the downhole tool for performing the tool
13 operation at the work site, whereby the downhole tool obtains the
14 image of the work site and performs the tool operation at the work
15 site during a single trip of the downhole tool into the wellbore.

16

17 2. The downhole tool of claim 1, wherein the imaging device is selected
18 from the group comprising a camera for optical viewing, an acoustic device, an
19 ultrasonic device, an infra-red device, an RF device, a microwave device, a
20 contacting device, a tactile device and a fiber optic device.

21

22 3. The downhole tool of claim 1, wherein the wellbore is a cased wellbore.

23

24 4. The downhole tool of claim 1, wherein the imaging device is a contacting
25 device comprising a series of projections extending from the downhole tool that
26 can engage with the wellbore and objects in the wellbore.

5 5. The downhole tool of claim 1, wherein the transmitter is selected from
6 the group comprising an electromagnetic transmitter, a fluid acoustic
7 transmitter, a tubular fluid transmitter, a mud-pulse transmitter, a fibre optics
8 transmitter and a conductor wire transmitter.

9

10 6. The downhole tool of claim 1, wherein the end work device is selected
11 from the group comprising a fishing tool to engage with a fish downhole, a
12 whipstock, a diverter, a re-entry tool, an anchor, a packer, a seal, an inflatable
13 packer, a plug, a perforating tool, a fluid stimulation tool, an acidizing tool, a
14 fluid fracturing tool, a milling tool, a cutting tool, a patch tool, a drilling tool, a
15 cladding tool, a welding tool, a deforming tool, a sealing tool, a cleaning tool,
16 a device for installing a device in the wellbore; a device for removing a device
17 downhole; a testing device for performing a test in the wellbore; an inspection
18 device; and a tool for engaging with a downhole object to perform a desired
19 operation.

20

21 7. The downhole tool of claim 1 further comprising a computer having at
22 least one processor for controlling the operation of the end work device.

23

24 8. The downhole tool of claim 1, wherein the end work device is movable
25 radially and longitudinally relative to the wellbore.

26

5 9. The downhole tool of claim 1 further comprising a memory positioned for
6 recording data from the sensor for data retrieval when the service tool is
7 brought back to the surface.

8

9 10. The downhole tool of claim 1 further comprising a memory pre-
10 programmed with a work site data model for correlating data generated
11 downhole with pre-programmed work site data to facilitate the identification of
12 the work site.

13

14 11. The downhole tool of claim 10, wherein the transmitter generates signals
15 for transmission to the surface representative of the data correlation and, thus,
16 of the work site data generated downhole.

17

18 12. The oilfield tool of claim 11, wherein the transmitter communicates with
19 other equipment positioned downhole in the wellbore.

20

21 13. The downhole tool of claim 1 further comprising a receiver associated
22 with the downhole tool for receiving signals sent from the surface to the
23 downhole tool, with the receiver communicating with a processor in the
24 downhole tool.

25

26 14. The downhole tool of claim 1 further comprising a formation evaluation

5 sensor adjacent the lower end of the tubing.

6

7 15. The downhole tool of claim 1 further comprising at least one sensor for
8 determining an operating condition of the downhole tool during drilling of the
9 wellbore, said at least one sensor selected from the group comprising
10 temperature, pressure, fluid flow, tool orientation, pull force, gripping force, tool
11 centerline position, tool configuration, inclination, and acceleration.

12

13 16. The downhole tool of claim 1, wherein the imaging device detects objects
14 positioned downhole of the tool.

15

16 17. The downhole tool of claim 1, wherein the imaging device is an ultrasonic
17 device positioned in the downhole tool to provide images of the work site
18 located downhole of the downhole tool.

19

20 18. The downhole tool of claim 17, wherein the ultrasonic device includes a
21 at least one transmitter for transmitting signals to the work site downhole of the
22 downhole tool and a receiver for receiving signals reflected by the work site.

23

24 19. The downhole service tool of claim 18, wherein the imaging device
25 operates the transmitter by sweeping a preselected frequency range to obtain
26 an effective operating frequency and continues to operate the transmitter at

5 such effective frequency to generate data representative of attributes of the
6 work site.

7

8 20. The downhole tool of claim 1, wherein the imaging device is beam
9 steered to generates data representative of the properties of the work site.

10

11 21. The downhole tool of claim 1, wherein the imaging device includes a
12 sensor that is rotated to generate data representative of the properties of the
13 work site.

14 22. The downhole tool of claim 1, wherein the end work device is a cutting
15 device that performs cutting with a high pressure fluid.

16

17 23. The downhole tool of claim 1, wherein the end work device is a reentry
18 device that includes an orienting device that can be oriented to enter into a
19 lateral wellbore intersecting the wellbore.

20

21 24. The downhole tool of claim 23, wherein the orienting device is selected
22 from a group of devices consisting of a knuckle joint, a flexible joint that is
23 operated by a control circuit in the downhole tool, a flexible joint that is
24 remotely operable, and a deflection device that reorients the downhole when
25 said deflection device is urged against the wellbore.

26

5 25. The downhole tool of claim 1 further comprising two spaced apart
6 isolators, said isolators isolating a zone of interest in the wellbore.

7

8 26. The downhole tool of claim 25 further comprising a device for injecting
9 fluid enterpriser into the zone of interest to perform testing of the zone of
10 interest.

11

12 27. The downhole tool of claim 25, wherein the isolated zone is selected from
13 the group consisting of a perforated zone, and juncture between the wellbore
14 and a lateral wellbore.

15

16 28. The downhole tool of claim 1, wherein the imaging device is a tactile
17 device having al least one probe that extends from the downhole tool to make
18 contact with the work site to provide signals representative of the physical
19 attributes of the work site.

20

21 29. A method of imaging a location constituting a work site of interest at
22 which a tool operation is to be performed in a pre-existing wellbore and
23 performing a work at the work site during a single trip, comprising:

24 (a) providing a tubing extending from the surface down into the
25 wellbore, a sensor adjacent the lower end of the tubing for sensing
26 properties associated with the work site and generating data

5 representative of the work site, a transmitter for receiving the data
6 and transmitting signals representative of the data to the surface
7 and an end work device adjacent the lower end of the tubing for
8 performing the desired tool operation;

- 9 (b) extending the tubing into the wellbore toward the work site;
10 (c) sensing properties associated with the work site downhole;
11 (d) generating data representative of the image of the work site;
12 (e) transmitting signals representative of the data to the surface; and
13 (f) performing the desired tool operation at the work site location
14 before removing the tubing from the wellbore.

15

16 30. A method of imaging a work site and performing an end work at the work
17 site in a pre-existing wellbore during a single trip into the wellbore, comprising:

- 18 (a) conveying a downhole tool into the wellbore, said downhole tool
19 having an imaging device for imaging a work site in the wellbore,
20 a device for isolating the work site, and an end work device for
21 performing a desired work at the work site;
22 (b) isolating the work site;
23 (c) imaging the work site by the imaging device; and
24 (d) operating the end work device to perform a desired operation at
25 the work site.

26

5 31. A method of imaging a location constituting a work site of interest in a
6 preexisting wellbore at which a desired operation is to be performed without
7 removing the tool from the wellbore, comprising:

8 (a) positioning a downhole tool adjacent the work site, said downhole
9 tool having an imaging device for sensing properties associated
10 with the work site and generating data representative of the work
11 site, a transmitter for receiving the data and transmitting signals
12 representative of the data to the surface and an end work device
13 for performing the desired tool operation;

14 (b) generating data representative of the work site and transmitting
15 signals representative of the data to the surface by the transmitter;
16 and

17 (c) performing the desired tool operation at the work site location
18 before removing the tool from the wellbore.
19

20 32. A downhole service tool; comprising;

21 (a) a packer adjacent a lower end of the tool, said packer having a
22 packing member on a housing that forms a seal between the
23 housing and a work site in a preexisting wellbore when a fluid is
24 injected into the packing member; and

25 (b) a sensor uphole of the packer for providing data representative of
26 an image the work site when the downhole tool is conveyed into

5 the wellbore for setting the packer in the wellbore.

6

7 33. A downhole oilfield service tool for imaging a work site in a wellbore and
8 for performing a desired operation at the work site without requiring retrieving
9 the service tool from the wellbore prior to performing the desired operation, said
10 service tool conveyable into the wellbore by a tubing extending from a surface
11 location toward and adjacent the work site, comprising:

12 (a) an ultrasonic sensor adjacent a lower end of the tubing for
13 providing an image of the work site and generating data
14 representative said image;

15 (b) a transmitter associated with the service tool for receiving the data
16 generated by the sensor and transmitting signals representative of
17 said data to the surface; and

18 a milling tool adjacent the lower end of the tubing for performing
19 a cutting operation at the work site based at least partially upon
20 said data without retrieving the service tool from the wellbore prior
21 to performing the desired operation.

22

23 34. A downhole service tool for entering into a branch wellbore from a
24 juncture at a main wellbore to perform an end work at a work site in the branch
25 wellbore during a single trip into the main wellbore, comprising:

26 (a) a sensor adapted to obtain data for an image of the juncture;

5 (b) a control circuit in the service tool for receiving the data from the
6 sensor and transmitting signals representative of said data to the
7 surface to obtain the image of the juncture; and
8 a tool orientation device in the service tool, said device adapted to
9 be operated downhole by the control circuit, to cause the service
10 tool to enter the branch wellbore; and
11 an end work device for performing the desired end work at the
12 desired work site in the branch wellbore, whereby the service tool
13 can locate the juncture, enter into the branch wellbore from the
14 main wellbore and perform the desired operation at the work site
15 in a single trip.

16

17 35. The downhole service tool of claim 34, wherein the tool orientation
18 device is selected from a group comprising, a knuckle joint that is controlled
19 from a command from the surface, a knuckle joint that is controlled downhole,
20 a plurality of independently adjustable pads, and a member that extends
21 outward from the service tool to urge against the wellbore to cause the service
22 tool to move transverse to the wellbore axis.

23

24 36. A downhole service tool for imaging a selected work site in a wellbore
25 and performing a welding operation at the selected work site in a wellbore
26 during a single trip, comprising:

- 5 (a) a sensor adapted to obtain data to image the work site;
- 6 (b) a control circuit in the service tool for receiving the data from the
- 7 sensor and transmitting signals representative of said data to the
- 8 surface to obtain the image of work site; and
- 9 a welding device in the service tool, said welding device adapted
- 10 to be operated downhole by the control circuit to perform the
- 11 welding operation at the work site during the single trip.

12

- 13 37. The downhole service tool of claim 36, wherein the selected work site is
- 14 selected from a group comprising a joint between casing in a main wellbore and
- 15 a branch wellbore formed from the main wellbore and a packer.

16

- 17 38. A downhole oilfield service tool conveyable into a wellbore for imaging
- 18 a location constituting a work site of interest downhole and performing a testing
- 19 operation at the work site during a single trip of the tool in the wellbore, the tool
- 20 comprising;

- 21 (a) a sensor adjacent for sensing properties associated with the
- 22 desired work site in the wellbore and generating data
- 23 representative of the work site;
- 24 (b) a transmitter for receiving the data from the sensor and
- 25 transmitting signals representative of said data to the surface; and
- 26 a pair of spaced apart seals on the service tool to seal at least a

5 portion of the work site of interest between the pair of seals; and
6 (d) a testing device in the tool to perform a selected test in the sealed
7 work site, during the single trip.

8

9 39. The downhole service tool of claim 38, wherein the selected work site is
10 a perforated zone.

11

12 40. The downhole service tool of claim 39, wherein the testing device
13 performs a test selected from the group comprising pressure test of a sealed
14 region, pressure build-up over a time period, temperature test, temperature
15 build-up over a time period, reservoir analysis, formation evaluation, resistivity
16 of formation fluids, sample collection, formation fluid analysis, and hydrocarbon
17 content of formation fluids.

18

19 41. A downhole oilfield service tool conveyable into a wellbore for imaging
20 a location constituting a work site of interest downhole and performing a
21 workover operation at the work site during a single trip of the tool in the
22 wellbore, the tool comprising;

23 (a) a sensor adjacent for sensing properties associated with the
24 desired work site in the wellbore and generating data
25 representative of the work site;

26 (b) a transmitter for receiving the data from the sensor and

5 transmitting signals representative of said data to the surface; and
6 a pair of spaced apart seals on the service tool to seal at least a
7 portion of the work site of interest between the pair of seals; and
8 (d) a device for injecting a pressurized fluid into the sealed portion of
9 the work site to perform the workover operation, during the single
10 trip.

11

12 42. The downhole service tool of claim 41, wherein the work site of interest
13 is a perforated region and the sealed portion includes at least one perforation.

14

15 42. The downhole service tool of claim 41, wherein the fluid is selected from
16 a group comprising cement slurry, polymer, water, steam, chemicals, and
17 acidizing fluids.

18

19 43. The downhole service tool of claim 41, wherein the workover operation
20 is selected from the group comprising injecting fluids into a perforated zone to
21 improve hydrocarbon production, sealing of a zone to prevent production of
22 fluids therefrom, cementing, fracturing, and cleaning.

23

24 44. A downhole visual imaging tool for obtaining an image of a predetermined
25 area of interest within a wellbore having substantially non-transparent fluid
26 therein, the imaging tool comprising:

- 5 (a) a tool body conveyable into the wellbore;
- 6 (b) a seal for blocking fluid communication to the area of interest , the
- 7 tool body having a device for providing a fluid seal between the
- 8 imaging tool and the work site when the imaging tool is placed a
- 9 predetermined distance from the work site;
- 10 a fluid injection system for displacing the non-transparent fluid
- 11 between the imaging tool and the work site with a substantially
- 12 transparent fluid; and
- 13 (d) a camera associated with the imaging tool for taking an image of
- 14 the work site.

15

16 45. The imaging tool of claim 44, wherein the tool body is conveyable into

17 the wellbore by a conveying device selected from a group consisting of a

18 wireline, a tubing and a traction device that can move the downhole imaging

19 tool through the wellbore.

20

21 46. The imaging tool of claim 44, wherein the camera is adapted to be

22 remotely oriented in a desired direction to take an image of the work site.

23

24 47. The imaging tool of claim 44 further having a control unit at the surface

25 for receiving data from the camera and for displaying the image of the work

26 site.

5 48. The imaging tool of claim 47, wherein the control unit controls the
6 operation of the fluid injection system.

7

8 49. The imaging tool of claim 44 further having a control circuit within the
9 imaging tool for automatically controlling the operation of the fluid injection
10 system and for operating the camera to obtain the desired image of the work
11 site according to programmed instructions provided to the control circuit.

12

13 50. The imaging tool of claim 44, wherein the imaging tool provides a multi-
14 dimensional view of the work site from data provided by the camera.

15

16 51. The imaging tool of claim 44, wherein the fluid injection system
17 comprises:

18 (i) a source of substantially transparent fluid; and

19 (ii) a fluid transfer mechanism for displacing the at least a portion of
20 the substantially non-transparent fluid with the substantially
21 transparent fluid wellbore.

22

23 52. The imaging tool of claim 51 further having a fluid communication line
24 coupled to the fluid chamber for retrieving the substantially transparent fluid
25 from the wellbore into the fluid chamber.

26

5 53. The imaging tool of claim 52, wherein the fluid transfer mechanism is
6 coupled to the fluid communication line for causing the substantially transparent
7 fluid to flow from the wellbore into the fluid chamber.

8

9 54. The imaging tool of claim 44, wherein the device for providing the seal
10 is a packer.

11

12 55. A method for imaging a work site of interest located within a wellbore
13 below a surface location, the wellbore containing a substantially non-transparent
14 fluid therein, said method comprising:

- 15 (a) setting a fluid seal a predetermined distance above the work site;
16 (b) displacing the substantially non-transparent fluid between the work
17 site and the seal with a substantially transparent fluid; and
18 taking an image of the work site with a camera placed between
19 the seal and the work site.

20

21 56. A method for imaging a work site of interest located within a wellbore
22 containing a substantially non-transparent fluid therein, said method comprising:

- 23 (a) conveying an imaging tool within the wellbore to a location above
24 the work site;
25
26 (b) isolating utilizing at least one seal the work site;

5 displacing the substantially non-transparent fluid in the work site
6 with a substantially transparent fluid; and
7 (d) obtaining an image of the work site with the imaging tool.

8

9 57. The method of claim 56 further having a circuit within the imaging tool
10 for communicating the image to a surface location.

11

12 58. An imaging tool for obtaining an image of a work site of interest within
13 a wellbore, comprising:

14 (a) a tool body conveyable into the wellbore;
15 (b) a flexible inflatable device on the tool body having a plurality of
16 spaced sensors arranged at a plurality of predetermined surface
17 locations on the inflatable flexible device, each such sensor
18 providing a signal in response to deformation of the surface
19 locations of the flexible inflatable device at which such sensor is
20 placed relative to a predetermined norm for such sensor; and
21 a computer, said computer receiving signals from the sensors in
22 the plurality of sensors when the inflatable flexible device is
23 inflated and urged against the work site and in response thereto
24 providing an image of the work site.

25

26 59. The imaging tool of claim 58, wherein the computer is located at a

5 surface location.

6

7 60. The imaging tool of claim 58, wherein the computer is located within the
8 imaging tool for computing the image of the work site downhole during
9 operation of the imaging tool.

10

11 61. The imaging tool of claim 58, wherein the imaging tool transmits data to
12 the computer representative of an image of the work site determined from the
13 sensors in the plurality of sensors.

14

15 62. The imaging tool of claim 58 further having a fluid injection system for
16 injecting a fluid into the inflatable flexible device.

17

18 63. A downhole oilfield service tool for imaging a work site in a wellbore and
19 for performing a desired operation at the work site during a single trip of the
20 service tool conveyed into the wellbore by a tubing extending from a surface
21 location toward and adjacent to the work site, comprising:

22 (a) an imaging device adjacent a lower end of the tubing for providing
23 an image of the work site; and

24 (b) an end work device adjacent the lower end of the tubing for
25 performing the desired operation at the work site based at least
26 partially upon the image of the work site during the single trip of

5 the service tool in the wellbore.

6

FIG. 1

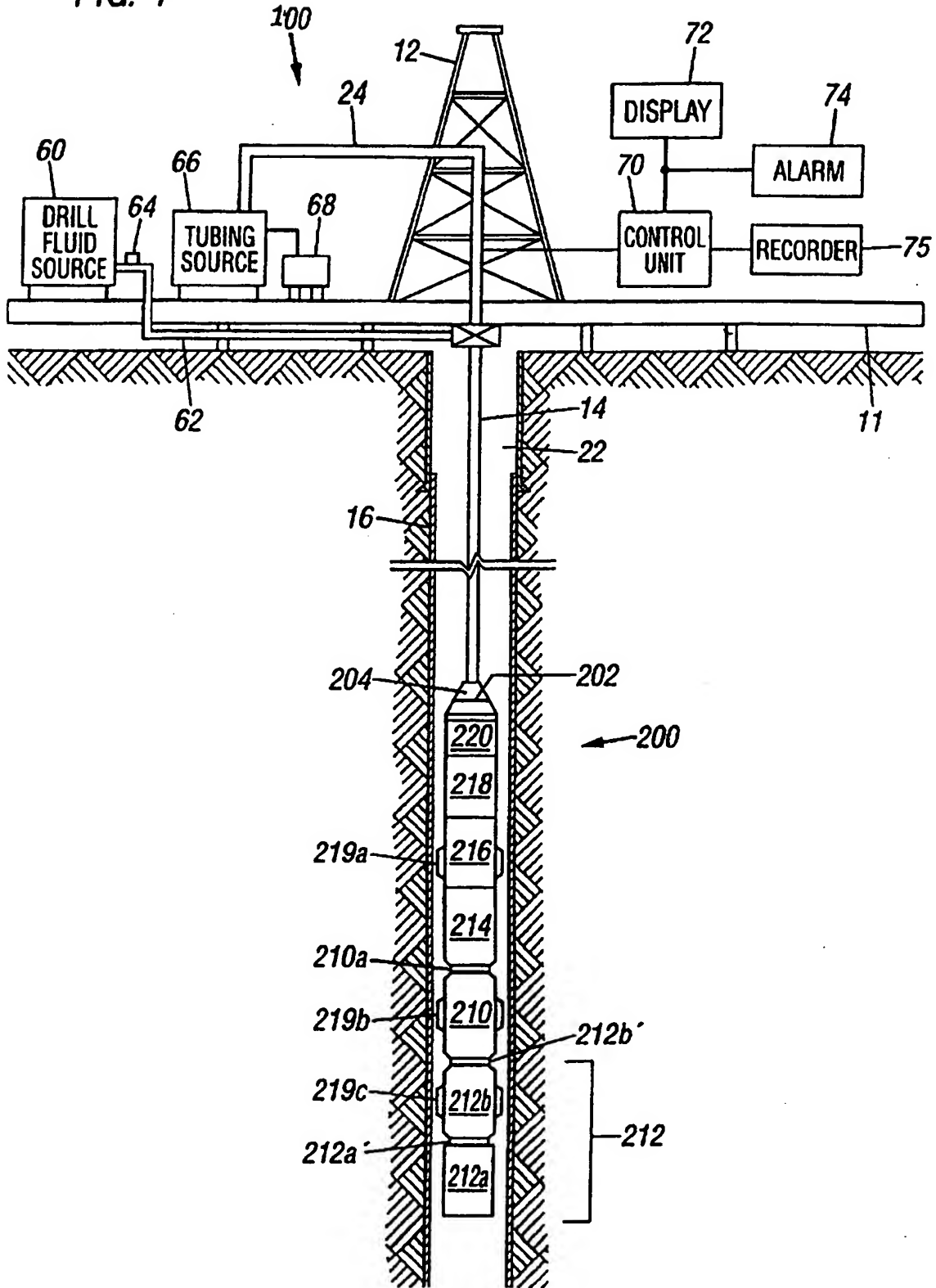


FIG. 2

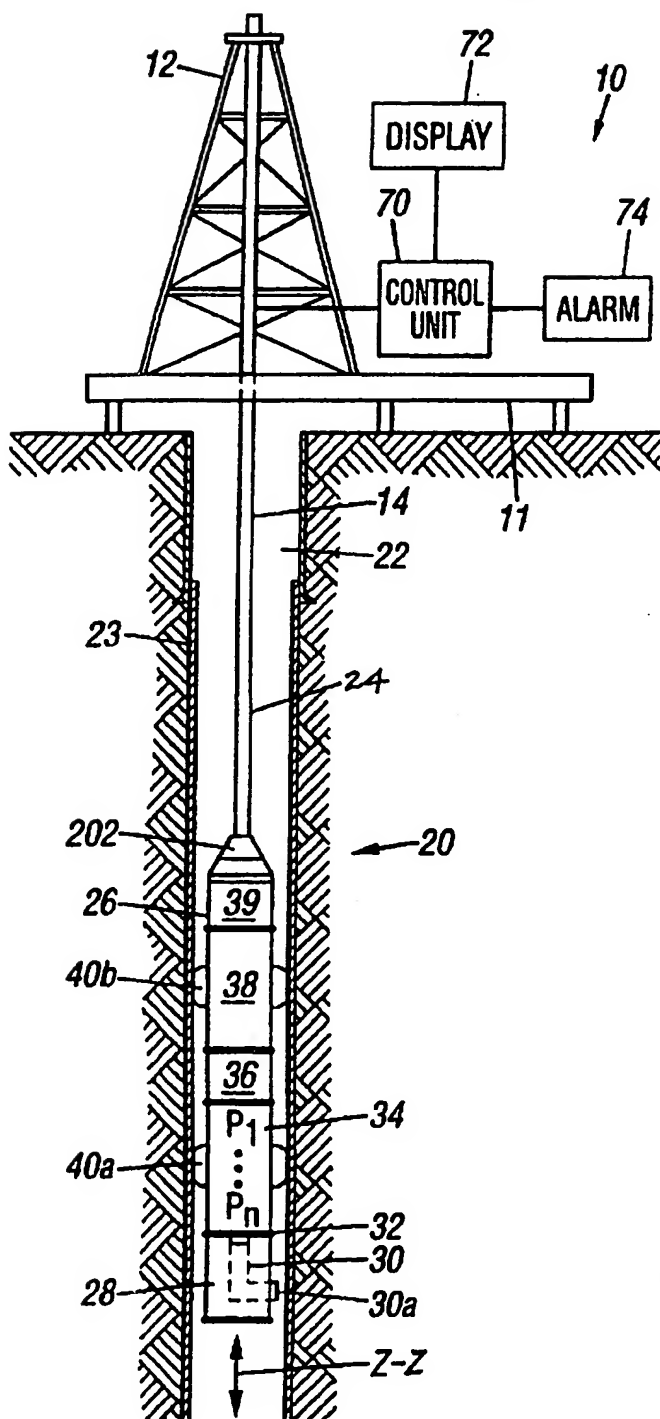


FIG. 1A

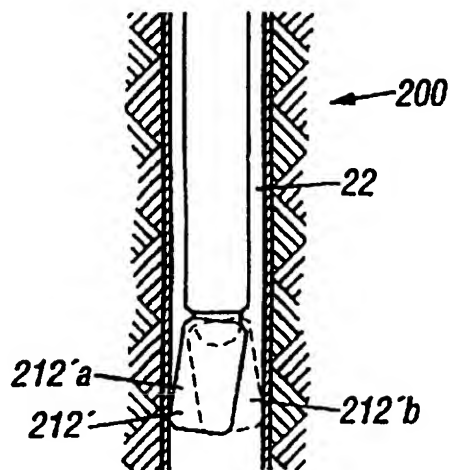


FIG. 2A

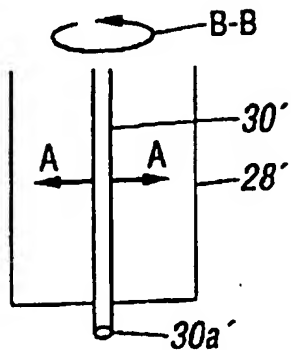


FIG. 3

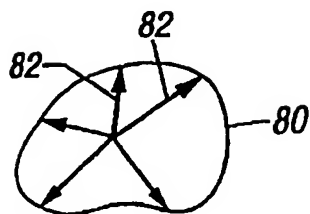


FIG. 4

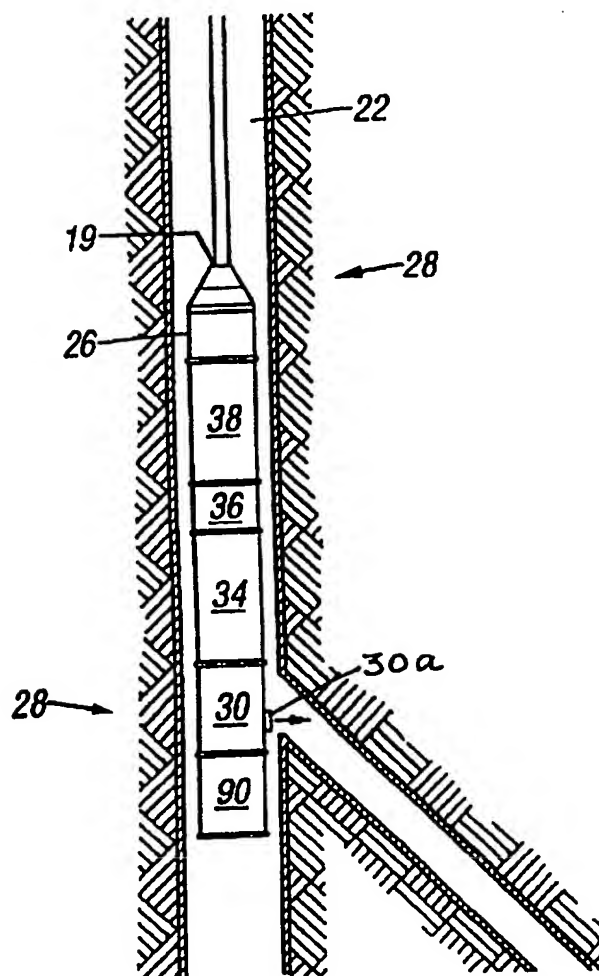


FIG. 2B

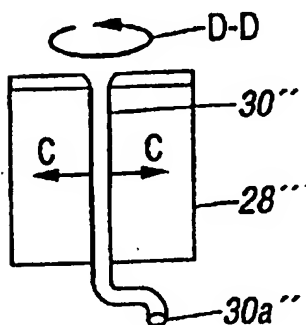


FIG. 2C

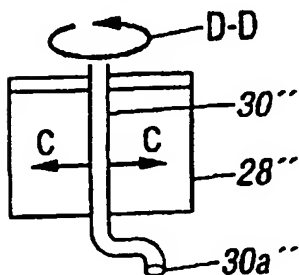


FIG. 5A

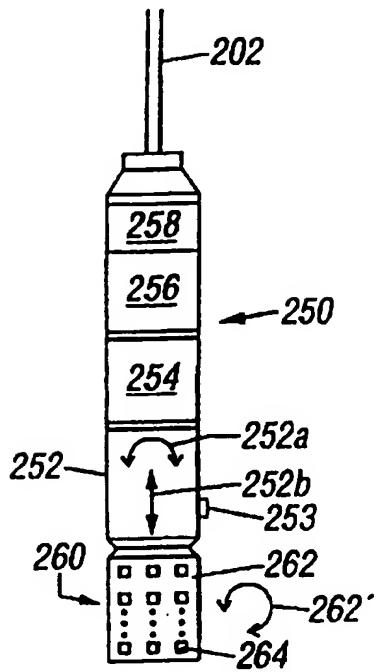


FIG. 5B

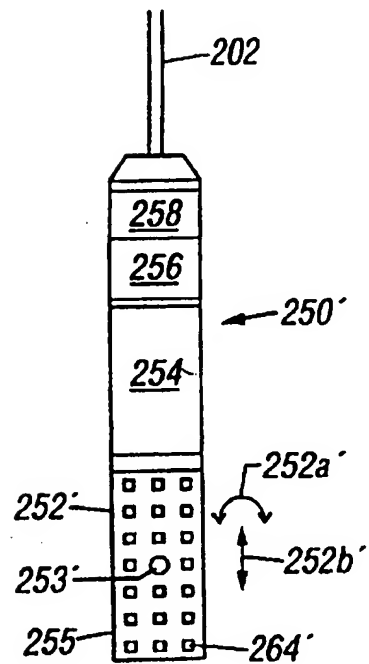


FIG. 5C

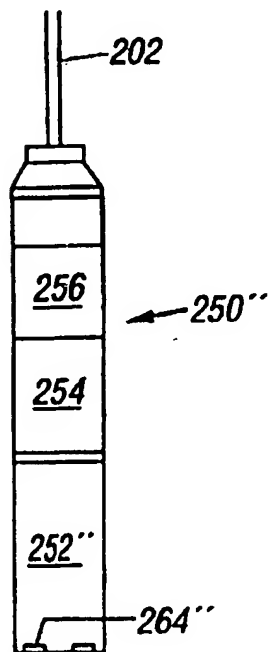


FIG. 5D

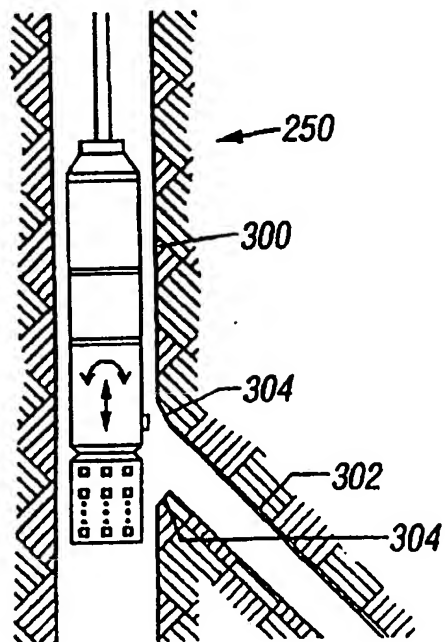


FIG. 6A

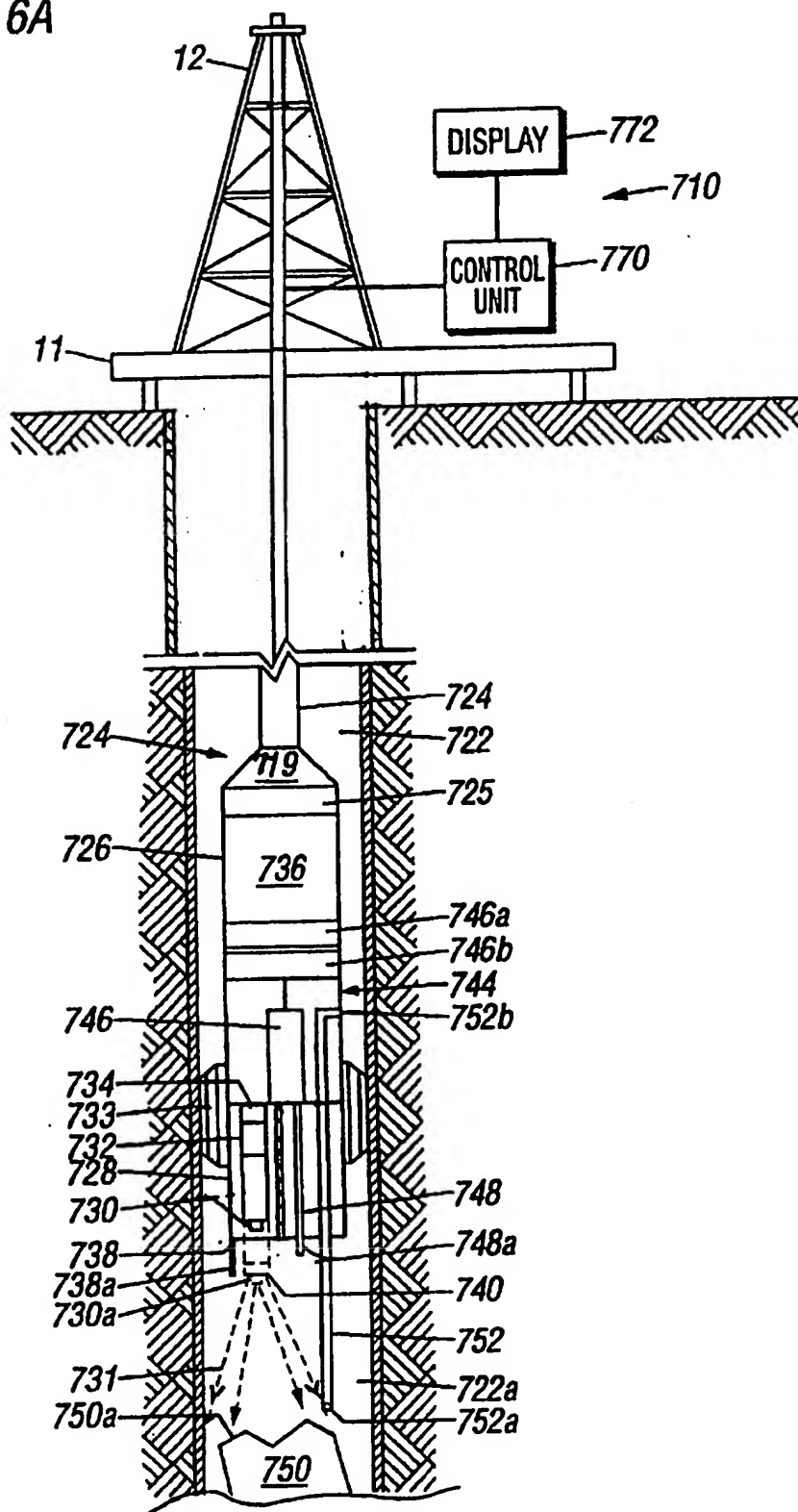


FIG. 6B

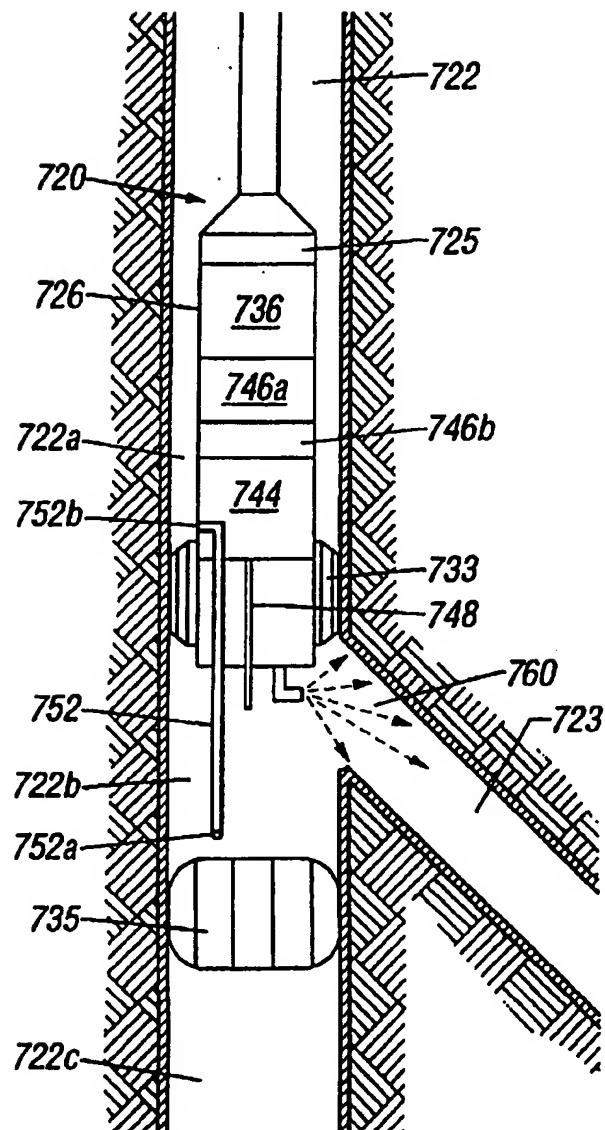


FIG. 6C

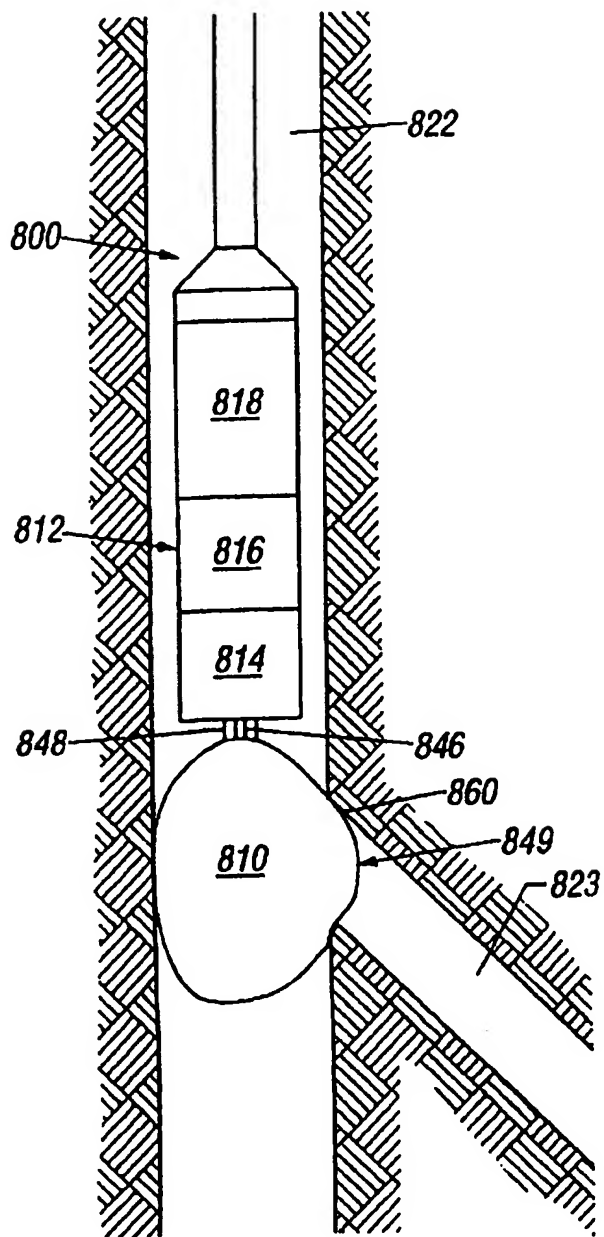


FIG. 6D

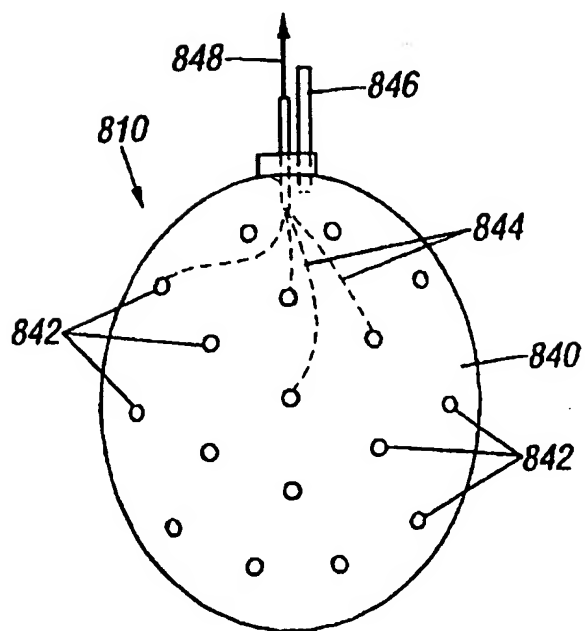


FIG. 7

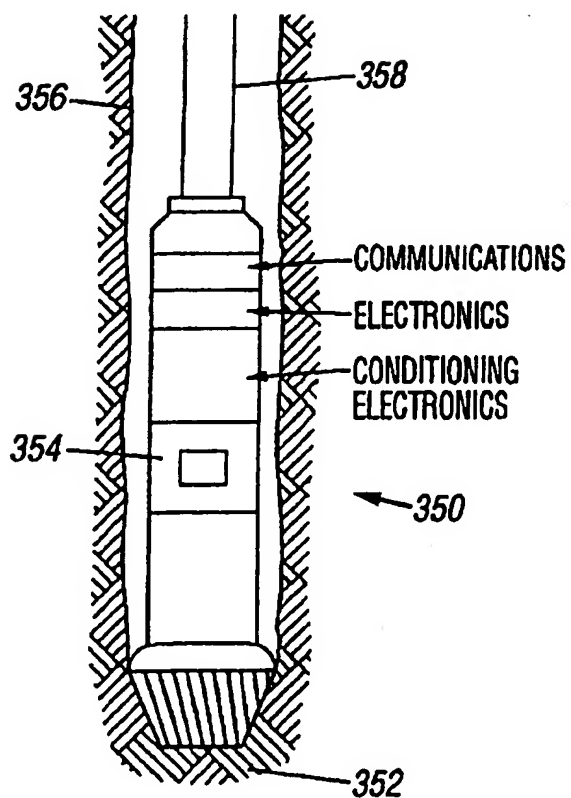


FIG. 8A

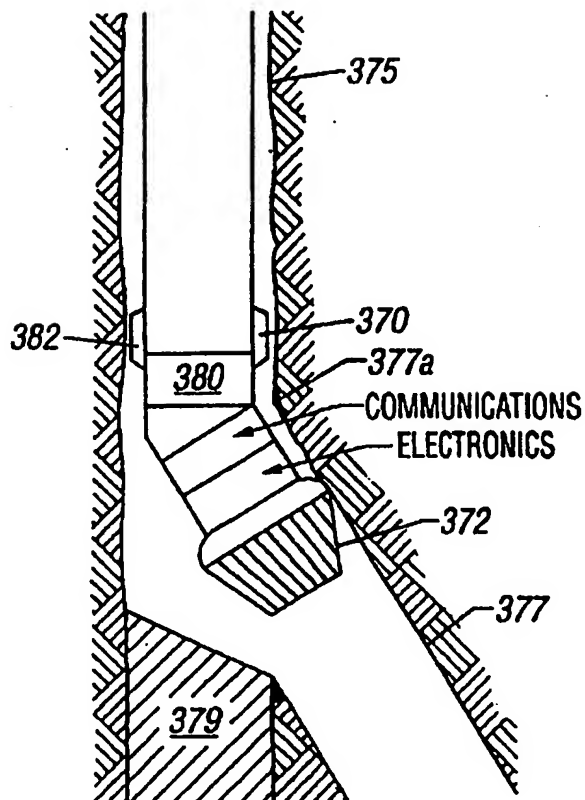


FIG. 8B

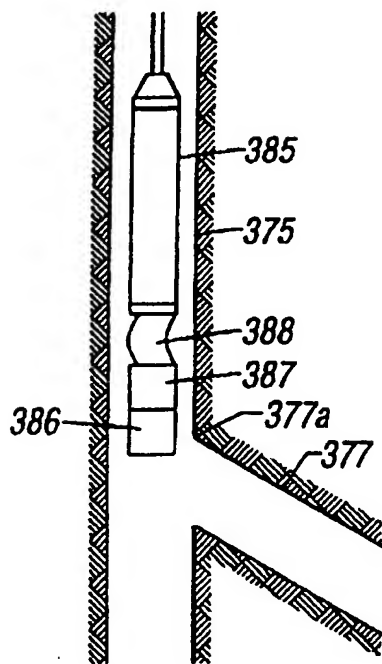


FIG. 8C

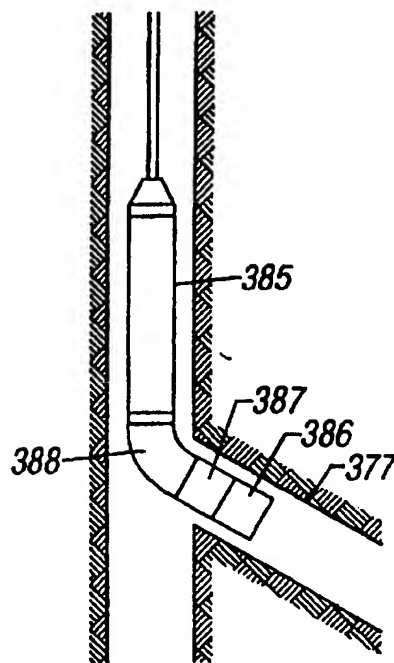


FIG. 8D

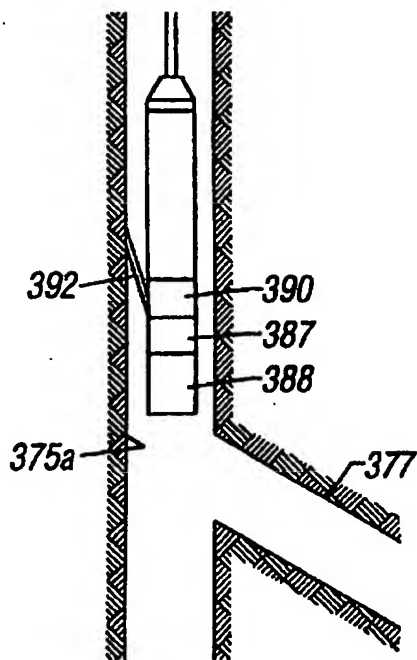


FIG. 9

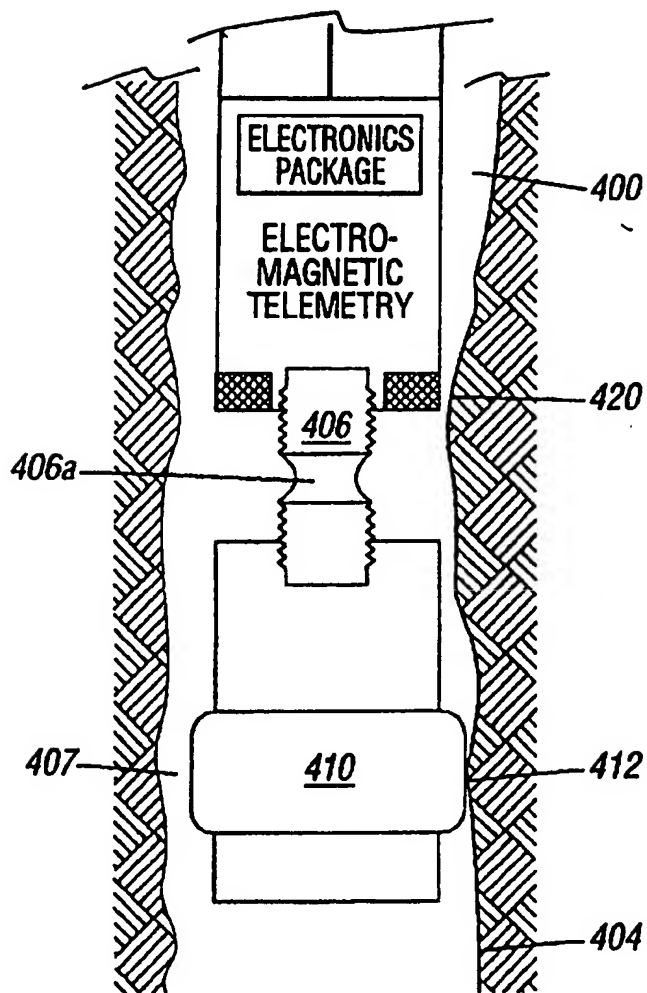


FIG. 10A

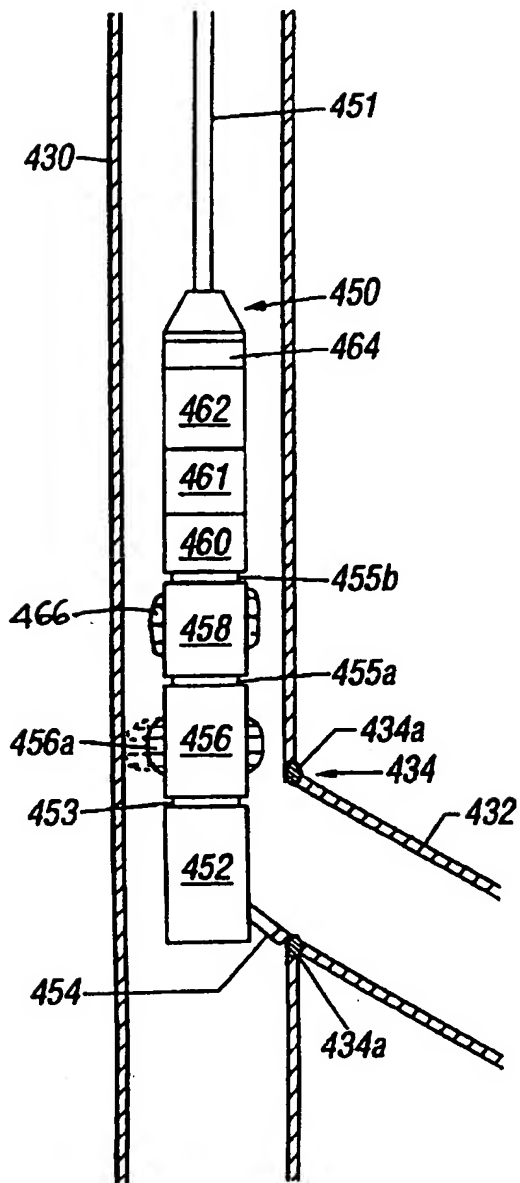


FIG. 10B

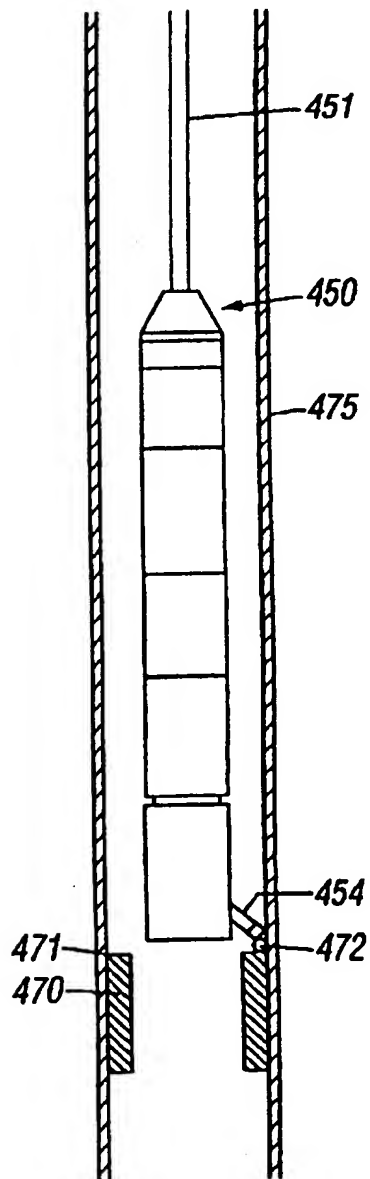


FIG. 11

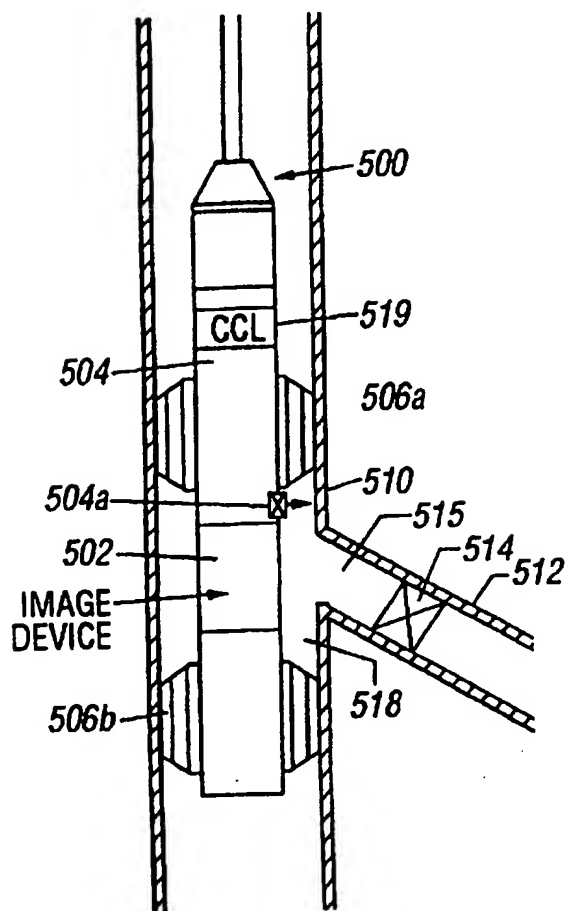


FIG. 12

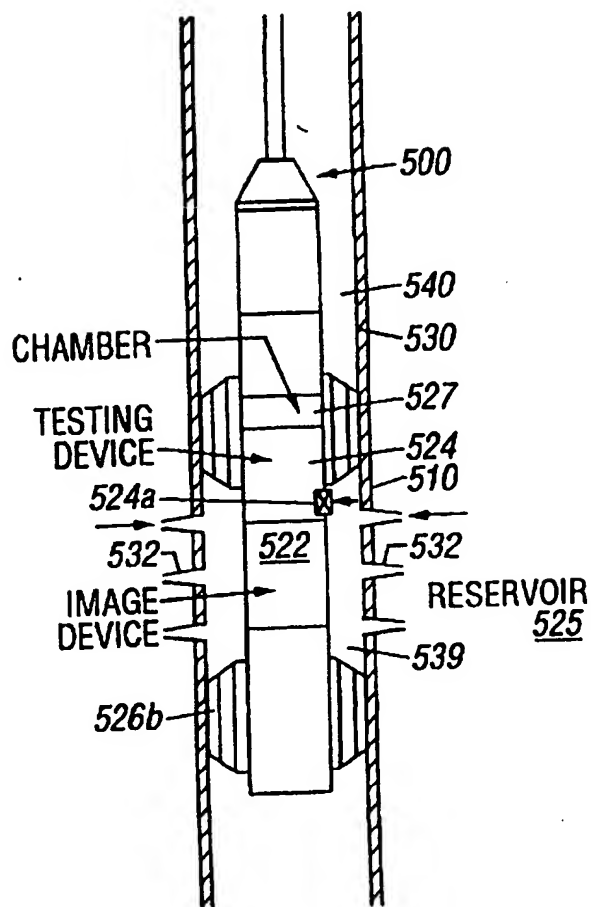


FIG. 13

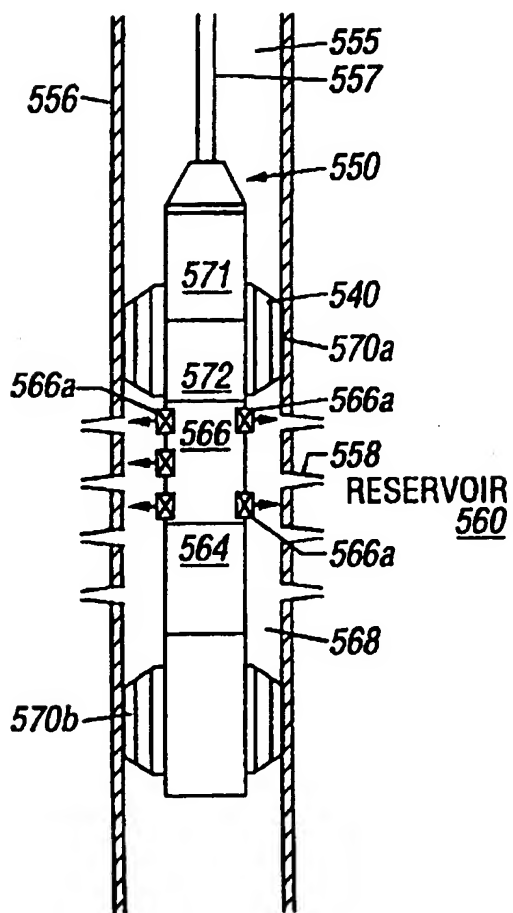


FIG. 14

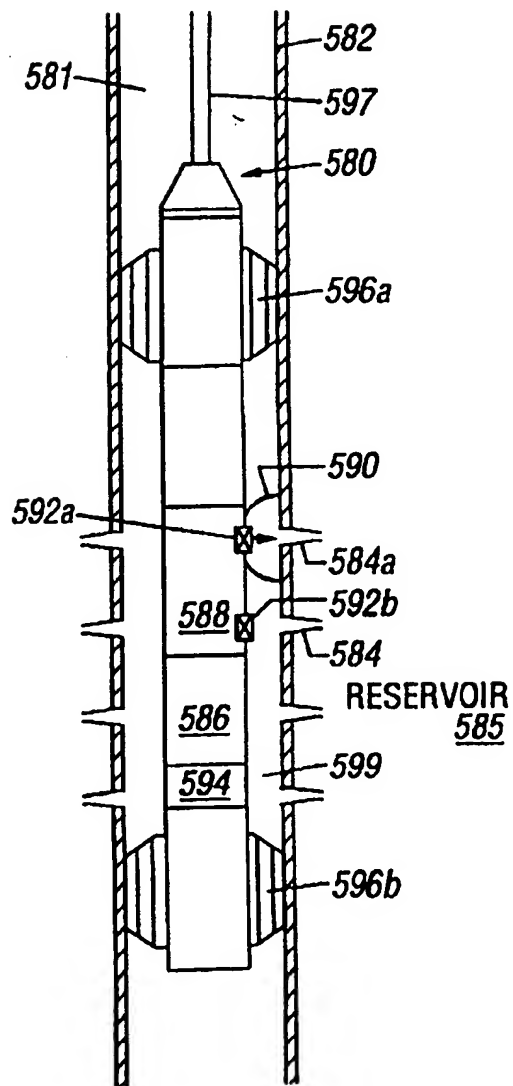


FIG. 15

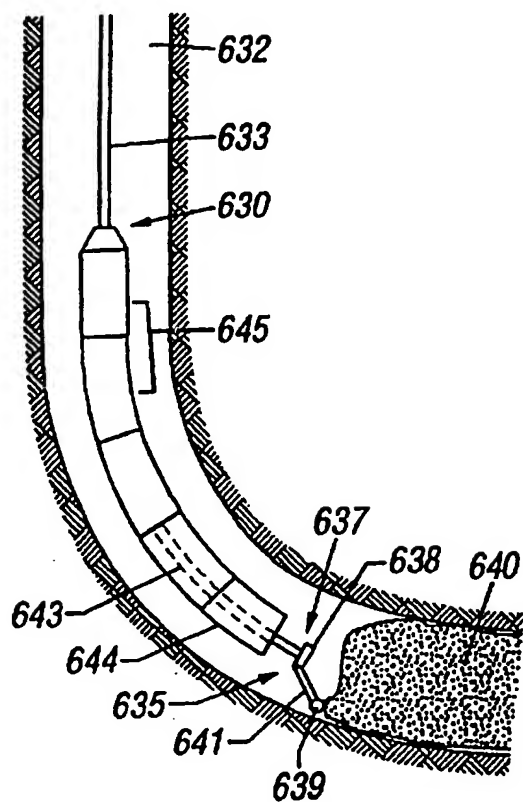


FIG. 16

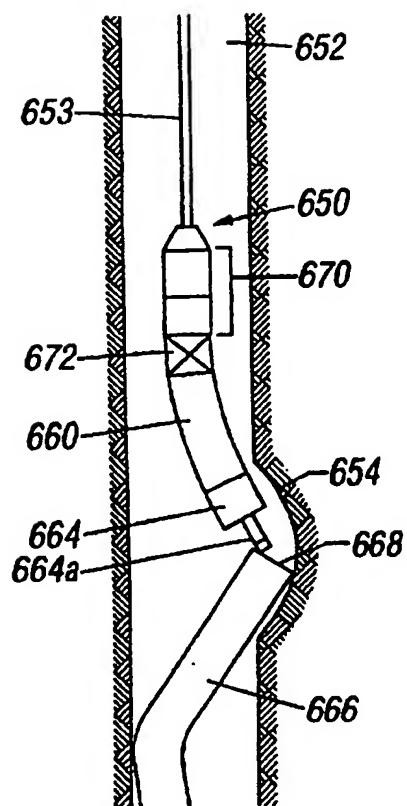
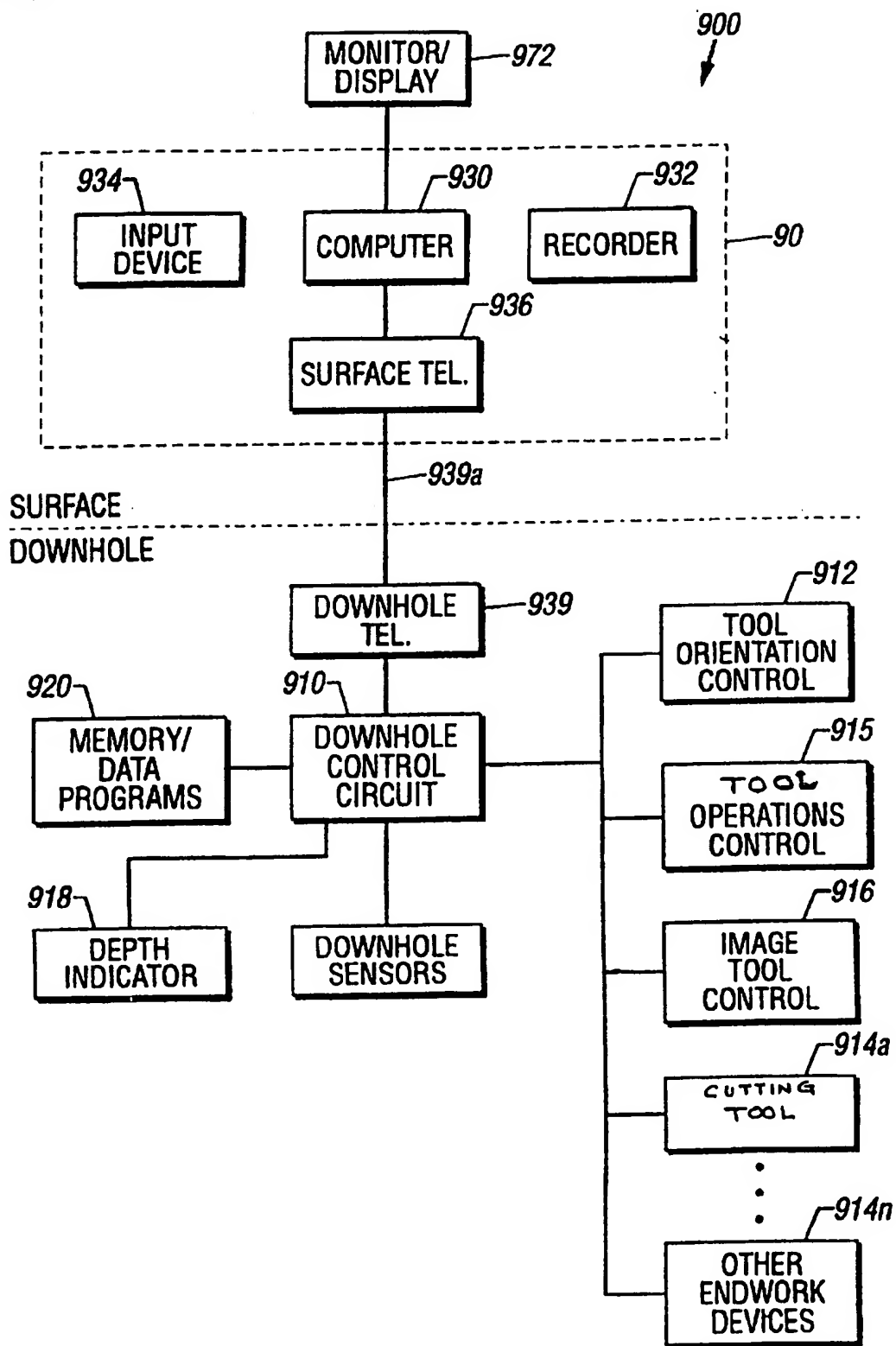


FIG. 17



INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 97/12524

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 E21B47/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 2 270 099 A (HALLIBURTON CO) 2 March 1994 see the whole document ---	1,29-34, 36,38, 41,44, 55,56, 58,63
A	GB 2 129 350 A (COLEBRAND LTD) 16 May 1984 ---	1-8, 29-33,63
A	FR 2 664 327 A (CLOT ANDRE ;TURON ROLAND (FR); UNGEMACH PIERRE (FR)) 10 January 1992 see the whole document ---	1,29, 44-56,63
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16 October 1997

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INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 97/12524

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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P,A	WO 97 12113 A (NATURAL RESERVES GROUP INC) 3 April 1997 see the whole document ---	1,29,34, 35
A	US 5 153 718 A (MASSAR JACK) 6 October 1992 ---	
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INTERNATIONAL SEARCH REPORT

Information on patent family members

Inter. .onal Application No

PCT/US 97/12524

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